GEOMETRICAL
RULES
Made Eaſy for the Uſe of
MECHANICKS
Concern'd in
BUILDINGS:

CONTAINING,

New and Infallible Methods, for Striking out from proper Centers, the Groyns of Arches regular and irregular, the Angle Brackets of Coves, Crowns of Beaufets circular or elliptick. With many other uſeful Problems relating to all Curve Lines, introduc'd in Building.

ALSO,

An ESSAY, on the Nature and Properties of Arches in general, mechanically conſider'd with Reſpect to their Shapes and Duration, exemplified by ſeveral Geometrical Figures, demonſtrating their Property and Powers, interſperſed with ſome Remarks on the intended Bridge at *Weſtminſter*. With a Propoſal for Building the Piers, by a Method practicable, ſo as to keep out the Water while erecting. The Whole deſign'd chiefly for the Information and Uſe of all *Building Artificers*, &c.

By ISAAC GADSDON.

LONDON:
Printed for JOHN WILCOX, at *Virgil's Head*, oppoſite the *New Church* in the *Strand*; and JAMES HODGES at the *Looking Glaſs* on *London-Bridge*. 1739.

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B M

THE PREFACE.

IT is a common Obſervation, that every Generation grows Wiſer, and I don't know any Thing that is a greater Confirmation, (to this old Saying) then to hear Artificers and Tradeſmen (when they meet together) relate their former Methods of Practice in their own Way of Buſineſs, and by comparing them with the Preſent, ſeem ſurpriz'd at the Improvements that have been made in their ſeveral Arts and Occupations whereunto they belong; From hence it's very plain, that there have been Men in all Ages, whoſe Ingenuity have led them out of the common Track, to find out nearer and better Methods to accompliſh their Deſigns, than they had ever been taught, or had before practic'd; And was a Man to indulge his Curioſity ſo far as to examine the ſeveral Employments of Life, I believe he would hardly find any that are ſo Mean and Trifling, but what would admit of a Difference in Practice, for how often may we find Men in trifling Employments, contending for ſuperiority of Judgment, and diſpute very *warmly about the different Methods of performing the ſeveral Branches of their Occupation. And if there is a Difference in the Practice of mean Employment, there is undoubtedly a great Deal more Difference to be diſcover'd in the Practice of thoſe Arts and Employments, that are of a more valuable Conſideration. The Art of Building alone will be ſufficient to juſtify the Truth of this Obſervation, for as this Art conſiſts of many Branches, it admits of many Practitioners, and as Mankind differ in their Abilities, it muſt conſequently cauſe a Difference in their Practice, and if a Man be ingenious, it gives him a great deal of Room to exerciſe his Fancy; for here, the Field of Art, layeth more often for the Mind to Range in, and is not confin'd to ſuch narrow Conceptions, as are very often found ſufficient to carry on a great many Employments of a lower Nature.*

Building if conſider'd in all it's Branches, is an Art very extenſive, and it muſt be allow'd to have receiv'd great Improvements within thoſe few Years paſt, but, whether that hath proceeded entirely from the many New Buildings lately erected, or from ſome other Cauſe, is not my preſent Enquiry.

The Theory, or deſigning Part of Building, hath always been eſteem'd preferable to the Practick, and Workmen have (for the Gene-

Generality) valued themſelves, and been eſteem'd by others, according as they have known more or leſs of it. For this Reaſon, one would think, that they would be very ready to embrace any Inſtruction, relating to the Theory of their Employment, for, I have very often known good Workmen, to be at a Loſs, for want of the Theory to direct them, and commit groſs Miſtakes, which the Knowledge of Lines would have prevented. For there is nothing that I know of, that can be of greater Service to any Mechanick, than to know the Theory of his Employment; and I have known ſeveral ingenious Workmen, belonging to the Building Trade, that by making cloſe Application to the Theory, have become good Surveyors.

And, indeed, they ought to be really ſo, that undertakes ſo ingenious an Employment; for it is not for every one that can make a fine Drawing, that is qualified to be a Surveyor, that being (in my Opinion) but the ſuperficial Part, for I can aſſure the Reader, that the original Deſigns of the great Inigo Jones, *were but poorly Drawn in Compariſon to the common Practice now known.*

I ſhould not have mention'd thoſe Drawings, had it not been to ſhew that there may be good Surveyors, without being fine Draughts-men, and the daily Practice of *ſome of our Moderns, plainly ſhew that there are fine Draughtſmen, that are not good Surveyors.*

By what I have here ſaid in Reſpect to Drawing, I do not mean to diſcourage any Perſon, from endeavouring to excel in that ingenious Art, nor to encourage any one to ſloven over a Deſign, but what I would obſerve, is only that there is a great deal of Difference between the Drawing and the knowing of Lines, in Reſpect to Building; for as the Knowledge of Lines, is the Baſe of the Mathematicks, it muſt conſequently be that of Architecture, and without them it would be impoſſible for one Man to convey his Ideas to another, in Reſpect to a Building; therefore, this the Architect ought to ſtudy well, and not only Lines, but Things themſelves, that he may be a Judge of the Materials required in a Building, and know (the better) how to apply them to their proper Uſe. In ſhort his Knowledge ought to be very Extenſive, his Fancy fruitful, his Judgment ſound, and be nicely juſt in all his Proportions, in Reſpect to Diſtance as well as Magnitude, that there may be a Symetry preſerved in all the Parts, both Internal and External; and if the Deſign be well adapted to the Situation, this Symetry will extend itſelf further, and bear ſome Analogy to the Landſkip it ſtands on.

This appears to me to be a very neceſſary Branch of Architecture, and I believe it is not always conſider'd in deſigning of a Building, or at leaſt is very ſeldom put in Execution, but whether it may be thought too nice for Obſervation, or whether it be not as yet rightly underſtood, I will not pretend to determine; but, however that be, I believe, it may (in many Situations) be introduc'd to a very good Effect, for it's a very common Obſervation, amongſt thoſe Perſons that have a Taſte of Gaiety and Dreſs, that Garments made of different Colours, and in different Shapes, will have a different Effect on the ſame Perſon that weareth them; So the Face of Nature, will undoubtedly bear the ſame additional Improvement, if the Complection and Features are rightly underſtood, and the Ornaments in a Building, are well adapted thereto by the Deſigner.

I ſhall forbear further Remarks, becauſe this hath already been obſerv'd in ſome Lectures *on* ARCHITECTURE *and* Harmonick Proportions *lately publiſh'd, in which, that Author by infallible* RULES, *and the Strength of a fine Imagination, hath carried this Obſervation to a greater Length than any Writer on this Subject, and hath there ſhew'd in a very delicate as well as* Poetical *Manner, what* Orders *of* Architecture *are moſt proper* *to be apply'd to particular* SITUATIONS, *which, if rightly choſen, will preſerve that* Symetry *I have been ſpeaking of, and conſtitute a Kind of* Harmony *which will always be the Reſult of* Proportion *and* Regularity.

From what hath been ſaid on this Subject of Building, I think it appears very plain that it muſt require a great deal of Judgment, to delineate a good Deſign, and it is as evidently plain as much Ingenuity is required in the Artificers, to perform the ſame in a Workman-like Manner, for altho' it be not abſolutely neceſſary for all Workmen to have deſigning Heads, yet they ought to have conceiving Ones, that they may readily diſcover the true Meaning of the Architect, by forming to themſelves a good Idea, not only of the Whole of what they are to perform, but of the Parts alſo; that they may take the neareſt and beſt Methods to work the ſame, and put them together in a Workman-like Manner.

This I muſt own in many Caſes of Building, is very eaſy to conceive, and in a great many others very difficult, therefore, I would adviſe the Reader, (if he hath not already) to ſtudy the Nature of Lines, by learning a little Geometry, and by obſerving what Inſtructions he will find contain'd in this Book, he may ſoon be able to perform his Work in any irregular

lar Form or Shape that is requiſite or practicable to be perform'd in any Building whatſoever.

But, for the Sake of thoſe that are unacquainted with the Nature of Lines, I have begun this Undertaking with defining the Properties of thoſe Geometrical Figures, that have any Relation to the enſuing Problems. To the End, that the Practitioner may comprehend the Theory or Hypotheſis in Building, and ſee the Reaſon of what he is about to perform, which I flatter myſelf will anſwer his Expectation, whenever he hath an Occaſion to make Uſe of them.

But before I proceed to give any further Account of my own Performance, I muſt beg Leave to take Notice of the Performance of others that have wrote (before me) on the ſame Subject, which are only two that I know of, and they are Mr. Halfpenny *and Mr.* Hoare.

Mr. Halfpenny *in his Art of ſound Building, hath publiſh'd a Method to ſtrike out the Groins of Arches, the Angle-Brackets of Coves, and ſeveral other Things of the like Nature, and hath call'd it a Geometrical Method; how far the Contents will agree with the ſtrict Rules of Geometry, I ſhall leave thoſe learned Readers to judge, that have ſeen the Book; but for thoſe that have not, are to obſerve that his Method chiefly conſiſts in traceing of Lines, either by Way of Interſection, or* *or by drawing them Parrelel from one Line to another, but the Reſult of both Ways was this; that you are to prick in Nails at certain Points, (determin'd by proper Direction) and bend a Lath round the ſame, and with a Pencil ſtrike the Arch or Curve according as the Nails and Lath directs, and that will be the Groin or Angle-Bracket required. Such a Line, (I muſt own) will be like the Groin or Bracket ſought, but then the Trouble and Time that is required to get at it, is what put me on thinking on ſome better Method, that might be ſooner perform'd, and to a better Effect.*

Mr. Hoare *was the next that had any thing to ſay to the Publick on this Subject, and by a long and ſpecious Advertiſement in a News-Paper, I was prevail'd on to purchaſe his Book, not knowing but that he might have taken the ſame Method I intended to take myſelf. But peruſing his Performance, I found he had followed the ſame Track that Mr.* Halfpenny *had mark'd out before him, and had perform'd very little, except reducing Mr.* Halfpenny*'s Folio into a ſmall Quarto, and by that Means rendered his own Performance a fit Companion for the Pocket, both in Reſpect to the Size as well as Price.*

This I muſt own was a Diſappointment for I had waited ſeveral Years in Expectation of ſeeing moſt of Mr. Halfpenny's Deſigns new Modell'd, believing ſome one or other would have diſcover'd a better Method, and have given it to the Publick in a much better Manner.

How far I have exceeded in that Reſpect, I muſt now leave to the Judgment of the Practitioner, who undoubtedly muſt know whether it is not a nearer and a better Method to ſtrike an Arch or Curve from a Center, than it is to trace them out by Lines, and after all that Trouble, be obliged to prick in a Parcel of Nails, and prepare a Lath fit for that Purpoſe, before you can ſtrike out the Line you want.

Surely there doth not want any deep Penetration to determine this Affair, for as moſt of the enſuing Problems have their Foundations in Geometry, they will bear a Demonſtration; therefore, it will be no difficult Matter to diſcover which of the two Methods are moſt Practicable.

I am not inſenſible that ſome of the Problems will appear mean and trifling to ſuch who have no Occaſion for ſuch Inſtruction, (and it's very likely) will think I have been too Particular, but if they will pleaſe to conſider that this is intended for general Uſe, and if they have no Occaſion for ſuch low In-

Inſtruction, there are ſeveral others that may who are not ſo expert in their Buſineſs as they, beſides, it is the common Way of moſt Authors that pretend to inſtruct in any Art or Science, to begin with the firſt Rudiments of that Art, and by gradual Steps advance to thoſe Rules that are more difficult, and this Method I have endeavour'd to follow as near as the Subject will admit.

I muſt own, that I have omitted ſeveral Problems, that are to be met with in the Works of Mr. Halfpenny *or Mr.* Hoare, *which I think have little or no Relation with our preſent Methods of Building, but inſtead thereof, I have ſubſtituted others in their Room, which I conceive to be more uſeful, but to make the Reader amends; I have beſtow'd ſeveral Pages on the Nature and Property of Arches, in Reſpect to their Shape and Duration, which Subject, naturally led me to make ſome Remarks and Obſervations on the intended Bridge at* Weſtminſter, *and likewiſe on what hath been publiſh'd on that Subject; And if what I have ſaid there or in any other Part of this Work, ſhould be of any Service to Mankind, ſo far as to give them any uſeful Hints, whereby the Theory of Building may be improv'd, I ſhall not think my Leiſure Hours loſt or any Ways miſemploy'd.*

J. GADSDON.

B M

DEFINITIONS.

AN Angle is an Indefinite Space terminated by the Meeting of two Lines which interſect or touch each other on a Plane, and may be either right-lined, ed or mixt.

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A right-lined Angle is that which is made by the Interſection or Meeting of two right Lines, as A, the Point at *a*, being the Point of the Angle.

A curved Angle is that which is made by the Meeting of two Curves, or crooked Lines, as, *b*.

A Mixt is made by the Interſection of a right Line and a crooked or curve, as *c*.

Angles whether plain or ſpherical may be either right, acute, or obtuſe.

A right Angle is when one Line falls perpendicular on another, as *d*; it conſiſts of 90 Degrees or one Quarter of a Circle, a Circle being commonly divided into 360 equal Parts called Degrees.

An acute Angle is any Angle that is leſs than a right one, as E, or that conſiſts of leſs than 90 Degrees.

An obtuſe Angle is greater than a right one, or that conſiſts of more than 90 Degrees, as F; ſuppoſing the dotted Line in each Figure to repreſent the intended right Angle.

A Triangle is a Figure that hath three Sides and three Angles, as G.

Any three whereof being given (except the three Angles) the other three may be found.

In any Triangle the three Angles taken together are equal to two right ones. Wherefore having any two given, the third is known of Courſe by ſubſtracting the Sum of the given ones from 180 Degrees.

In a right-angled Triangle where one Angle is a right one, the other two are neceſſarily acute. And both together are equal to 90

Degrees,

B M

Degrees, wherefore one is always the Complement of the other to a Quadrant.

A Segment of a Circle, is a Part of a Circle terminated by a right Line leſs than the Diameter, and by a Part of the Circumference, as A.

CHAP. I.

On the CIRCLE, *&c. with their Properties.*

Firſt, A Circle is a plain Figure contain'd under one Line, as the Line AAA in *Fig.* 1. which Line is called the Circumference, or Periphery, and all ſtraight (or right) Lines paſſing through the Center *a*, and touching each Side of the Circle are call'd Diameters, as the Line B, the Half of which is called the Radius, or Semidiameter.

Half a Circle is called a Semicircle. All ſtreight Lines, as C, not paſſing through the Center of a Circle are called Chord Lines, and the Parts ſo cut off are called Arches or Segments of a Circle.

Secondly, An Ellipſis, or Oval, is a Figure contained under one Line, and differeth from a Circle according to the Difference of its Diameters,

meters, as in *Fig.* 2. the ſhorteſt Diameter B is called the Conjugate; the longeſt C is called the Tranſverſe.

Theſe Figures have ſeveral Properties, which I might enlarge upon, but as they will be of no Uſe in the following Sheets I omit them.

Thirdly, A Cylinder is a ſolid Body, round and long, whoſe Sides are parallel, or at equal Diſtance one from another, as in *Fig.* 3. the Ends being ſquare (or at right Angles) with the Sides muſt conſequently be a Circle, as A. But if they are cut obliquely, they become Ellipſis's, as the Section D, and according to what *Obliquity* the Ends are cut the *tranſverſe* Diameter will increaſe, but the Conjugate will always remain the ſame.

Fourthly, A Cone is a ſolid Body, round and wide at the Bottom, or Baſe, and diminiſheth to a Point at the Top reſembling a Sugar Loaf; ſee *Fig.* 4. It hath the ſame Properties that the Cylinder hath, in Reſpect to the Ellipſis and Circle; for if it be cut at right Angles to the Axis, or Middle Line A, that Section will form a Circle, but if cut obliquely, (as the Section B,) 'twill form an Ellipſis; but as the Ellipſis cut from a Cylinder can be enlarg'd larg'd but one Way, thoſe cut from a Cone may be enlarg'd both Ways, but not in the ſame Proportion. A Line made perpendicular thro' the Center is call'd the *Axis* of the Cone, and if the Top of it be cut off; the Part remaining is called the *Fruſtrum* of a Cone.

This Body admits of many more Sections and Properties, which would be of no Uſe to define here, and for that Reaſon are omitted; but as to theſe I have mentioned, I muſt deſire the Reader to take Notice of them; the Cylinder eſpecial'y. And if he doth not conceive the Sections by the Figures it will be beſt to make the Bodies themſelves of Wood or other ſoft Matter, and cut them according to Direction, and he will ſoon diſcover that a Cylinlinder cut obliquely will be an Ellipſis; and as all ſemicircular Arches are Half-cylinders, their Groins, or Miters, muſt conſequently be Half-Ellipſis's. But of this more hereafter.

CHAP. II.

Some Introductory Problems.

PROBLEM I.

On a right Line given as A, *to raiſe a Perpendicular.* Fig. 5.

OPEN your Compaſſes to the Length of the whole Line, fix one Point at *a*, and extend the other Point to *e*, and make a Scratch; then fix your Point in *c*, and make another Scratch at *e*, then take Half that Diſtance you have in your Compaſſes, and ſet it off on the given Line at A; and a Line drawn from the Point A, to the Point *e*, where the two Scratches interſect will be perpendicular to the given Line *a*, *c*.

PROBLEM II.

To raiſe a Perpendicular at the End of a Line given as A. Fig. 6.

Proceed as if you were to raiſe a Perpendicular from the Middle of the given Line, then draw the Line B, through the Interſection of the Scratches C at Pleaſure, then ſet off the ſame Diſtance you have in your Compaſſes upwards from C, on the Line B, and from thence draw a Line to the End of the given Line A, at *d* to *e*, which will be at right Angles, (or perpendicular) to the Line A.

PROBLEM III.

Any Part of a Circle being given to find the Center be it more or leſs than a Semicircle. Fig. 7.

Let ABC be the Segment (or Part of a Circle) given; draw the Chord Line AC, then raiſe a Perpendicular from the Middle E of the Line AC, at Pleaſure, then draw the Chord Line AB, and from the Middle D, of that Line, raiſe another Perpendicular and the Point F, where that interſects the other Perpendicular, will be the Center required.

PROBLEM IV.

A Line being given, divided into any Number of Parts; to divide another given Line in the ſame Proportion, as Fig. 8.

Suppoſe the Line A, divided into equal or unequal Parts, as, *a b c d e f g*, and the Line B be required to be divided in the ſame Proportion; make A the Baſe, and B the Hypothenuſe of a Triangle, draw the Line which compleats the Triangle, draw Lines from all the Diviſions, *a b c*, &c. parallel to that Line, and they will divide the Line B, in the ſame Proportion.

This is a very uſeful Problem, and may be ſerviceable to Workmen on ſeveral Occaſions; for if a Man hath any Moulding (that conſiſteth of many Members) ready drawn out, and wanteth another of the ſame Sort, either larger or leſs, this Method will give it him ſooner than to divide it anew; nay ſhould he want to lengthen or ſhorten any one Order, with its proper Pedeſtal and Entablature (if he hath Room to lay down the Lines) he may perform it by this Method. And if he hath not Room, it may be done in Parts, obſerving to ſet off each Line, or Part, in the ſame Angle.

Mr. *Halfpenny* and Mr. *Hoare* have been ſo fond of this Problem, as to make it the Baſis of moſt of their Schemes, and have carried it through all their Deſigns relating to Curves, in order to find out the Groyns of Arches; the Angle Bracket of Coves, and ſeveral other Deſigns of the like Nature. But I hope the Reader will find in the following Sheets a much better Method; a Method that will not require a great many Lines, no Nails, nor bended Laths to ſtrike the Curve; but performs it by Centers; this I ſhall endeavour to make eaſy and familiar to the Practitioner by giving the Theory as I go on, and deſcribing ſuch Inſtruments as are proper to perform it, and as the Trammel is the beſt and uſefulleſt Inſtrument, I muſt deſire thoſe Readers that are unacquainted with it to obſerve the following Deſcription.

A Trammel is form'd of two Pieces of Wood croſſing each other at right Angles in the Middle; (as in *Fig.* 9.) with a Grove plow'd in the Middle; and when fitted together the Groves muſt be cut, one into the other; the Length you muſt proportion according to your Deſign, and brace them as you ſee in the Figure. Then prepare a Rod with two moving Centers, or wooden Pins, and fit them to the Groves, ſo as they may ſlide up and down at Pleaſure; then uſe it in the following Manner.

Note, As Joyners and Carpenters very ſeldom want above half an Ellipſis in their Way of working the upper Part will be uſeleſs, and one in the Form of a T will do as well.

PRO-

PROBLEM V.

To ſtrike out an Ellipſis with a Trammel to any given Proportion. Fig. 10.

Suppoſe you would have one, 6 Feet by 4, take half your longeſt Diameter (which is 3 Feet) and ſet off from the Tooth or Pencil at the End of the Rod to make the Mark; and there fix one Center; then take Half the ſhorteſt Diameter and ſet off as before, and there fix the other Center, then apply the Rod to the Trammel by putting Centers or wooden Pins into the Groves and move the Rod quite round the Periphery A, B, C, D keeping the Centers in the Groves, and that will deſcribe the Ellipſis required.

PROBLEM VI.

To ſtrike out an Ellipſis with a Pair of Compaſſes to any given Proportion. Fig. 11.

Take the Difference between the two Diameters, and divide into 3 equal Parts, take two of them, and ſet off on each Side the Center on tranſverſe Diameter, as B and E, take the whole Diſtance between B and E in your Compaſſes, and fix one Point in either B or E, extend the other to the Conjugate Diameter, and where that Point falls on that Line as at D and F; from thoſe Points draw Lines at Pleaſure as you ſee in the Figure; then from B as a Center ſtrike the Arch A, and from E, the other Arch A; then from the Center F, ſtrike the Arch *a c b*; and from the Center D, the Arch *d* G *f*, and all thoſe Arches will meet where thoſe ſtreight Lines interſect and form an Ellipſis.

This Ellipſis will be as true a one as can be drawn with a Pair of Compaſſes, and fit for any Uſe; but if conſidered in a mathematical Way, it cannot have the true Properties of an Ellipſis, becauſe their Centers are always moving, whereas thoſe being fix'd can only ſtrike ſuch Curves as will co-incide, and appear very much like a true one. Beſides this Sort of Ellipſis may be drawn parallel, which the true ones cannot, becauſe they flow from a right Line and want to get into a Circle, as may be be eaſily prov'd by firſt drawing one, whoſe Conjugate Diameter ſhall not exceed an Inch, and the Tranſverſe not be leſs than two Feet: I ſay, if you endeavour to draw other Ellipſis's parallel to ſuch an Ellipſis, by increaſing both the Diameters alike, and draw a great Number you will have one at laſt very near a Circle;

and may be diſcover'd by meaſuring between the Diameters of the firſt and the laſt that they are not parallel, and if thoſe two are not 'tis impoſſible any other two ſhould.

PROBLEM VII.

To ſtrike out an Ellipſis with a String. Fig. 12.

This Method is moſt commonly made uſe of, and performs the ſame as a Trammel, if the String would not ſtretch, but as all Lines are of a ſtretching Nature, it cannot be uſed with that Certainty that in many Caſes is required, but may be made uſe of in a great many others, obſerving the following Method.

Take Half the Conjugate Diameter in your Compaſſes, and ſet one Point at the Center and the other at either End of the Tranſverſe, extend the other, and where that falls ſtick your Nails as at A and B, for the Center's; then take a String, or Line, the leaſt apt to ſtretch you can get, put it round the Nails and tye it to ſuch a Length that your Pencil C may juſt reach the End of one of your Diameters; then keeping the String equally tight, let it work round the Nails, and your Pencil will ſtrike this Ellipſis.

Note, There is another Method that may be made uſe of to ſtrike the Quarter of an Ellipſis; which is to fix a ſtreight Piece of Wood a-croſs a Drawing-Board, at right Angles with the Side, then take a Rod half the Length of of the Tranſverſe Diameter, and from the Pencil End ſet off Half the Conjugate Diameter on the lower Side of the Rod, and there ſtick in a Nail, or Pin, to work along the Edge of the Drawing-Board; the End next the Pin make round to work againſt the Edge of the Piece nail'd on the Board, and that will perform the ſame as a Trammel, as far as it will go.

The Definitions and Problems hitherto laid down are only introductory to what will follow, the Theory whereof depends upon them; which Definitions and Problems, if the Reader will but give himſelf a little Time and Application to underſtand, the following Propoſitions will be more eaſily perform'd and better underſtood.

CHAP. III.

PROBLEM I.

To find the Groin Arch of two Semicircular Arches that interſect or croſs each other at right Angles. Fig. 13.

THE Theory of this Problem depends on a Cylinder, which being cut obliquely will be an Ellipſis, and as all ſemicircular Arches are the Half of Cylinders, the Groins, or Miters, of ſuch Arches muſt conſequently be Half-Ellipſis's, and may be found by the following Method.

Suppoſe the Arch A, to riſe three Feet and Spand ſix, or any other given Proportion; let fall the Perpendicular B at one End of the Diameter C, and equal to it, which will be two Sides of a Square; then draw the Diagonal Line D, and that will be the Tranſverſe Diameter, and the Line C A will be the Conjugate, which ſet at right Angles in the Middle of the Tranverſe D, as the Line E, then take a Trammel, or String, and ſtrike the Ellipſis F, F, F, the Half of which will be the Groin ſought.

PRO-

PROBLEM II.

To find the Groin Arch of two ſemicircular Arches, that interſect one another obliquely, as in Fig. 14. Plate 2.

Suppoſe them of the ſame Demenſion as the laſt, or any other, you muſt draw the Plan of their Interſection as you ſee in the Figure, then draw the Diagonals, A and B, and they will be the Tranverſe Diameters, the Conjugates will always continue the ſame; then proceed as directed in *Prob.* I, and this Method will find out the Groin be the Angle of Interſection what it will.

PROBLEM III.

To find the Groin Arch of two Elliptical Arches, whoſe Tranſverſe Diameters are horizontal or level, and interſect at right Angles. Fig. 15.

Suppoſe it were required to find the Groin of the Elliptical Arch E, you muſt proceed as in *Prob.* I. to ſquare the horizontal tranſverſe Diameter A, and take the Diagonal Line B for your Tranſverſe Diameter of the Groin and the dotted Line C will be the Conjugate; proceed as before directed, and the Half of the Ellipſis K, K, K will be the Groins ought; and if the Arches croſs obliquely you muſt proceed as directed in *Prob.* II.

PROBLEM IV.

To find the Groin Arch of two Elliptical Arches, whoſe Conjugate Diameter is horizontal, and interſects at right Angles. Fig. 16.

In this you muſt proceed, as in the former, by ſquaring the horizontal Line A, (which in this Arch is the Conjugate Diameter) and take the Diagonal Line C, for a new Diameter, but whether it will be a Conjugate, or a Tranſverſe, the Diameters of your firſt Ellipſis will determine; for, if they are in the ſame Proportion, as the Side of the Square is to its Diagonal, the Groin Arch will be a Semicircle, but let the Proportion be what you pleaſe, if you take the dotted Line D, and the Line C, for the Diameters of the Ellipſis that is to form the Groin, they will tell you which will be the Conjugate, and which the Tranſverſe; but let that happen as it will, the Line C muſt always be the horizontal Diameter, and the Half-Ellipſis, or Circle, on either Side that Line will be the Groin ſought.

PRO-

PROBLEM V.

To find the Groin Arch of a ſemicircular Arch meeting with one that is Elliptical at right Angles, as in Fig. 17.

Notwithſtanding theſe Arches differ their Groins will be both alike, and may be found by drawing the Plan of their Interſection, and taking the Diagonal for the Tranſverſe Diameter, and the dotted Line A for the Conjugate, ſtrike the Ellipſis B, B, B, the Half of which will be the Groin ſought.

Note, All Arches that are of different Spand, and are to interſect each other, one of them muſt be elliptical, otherwiſe they will not riſe to the ſame Height and coincide one with the other; and if they are both elliptical and differ in Diameters, the Method is exactly the ſame.

PROBLEM VI.

To find the Groin Brackets, where a ſmall Arch is cut out of a larger, and both are Semicircles. Fig. 18.

When theſe ſmall Arches are cut off of large ones, it is commonly introduce a Window or

Door, and the Groin Brackets may be found by the following Method; draw the Plan of the great Arch A, then draw the little Arch B on the Side, as you ſee in the Figure; and from the Ends D D, of the Arch B, draw the Lines K and L, through the Middle Point, *c*, and either of them will be the Tranſverſe Diameter of the Ellipſis, *o o o*, and the Conjugate will be the Diameter of the great Arch A, and the two Groin Brackets will be the Arches R T, which are cut off by the Line L; theſe you muſt place exactly over their reſpective Diagonals L and K, and let the two flatteſt Ends meet together and ſtand uppermoſt, then will the little Arch B meet and coincide with the great Arch A, and be the Quadrant O, D, T, D.

I could give ſeveral other Problems of this Nature, but I believe the Reader by this Time is ſo well acquainted with my Method of Proceeding, that to give any more would look like an Affront offer'd to his Underſtanding; for if he hath diſcover'd the Theory of what I have hitherto advanced on this Subject, there can be no Arches that are compos'd of the Ellipſis, or Circle, but he may find out the Groin thereof, let them meet or croſs each other how they will.

PROBLEM VII.

To find the Angle or Corner Bracket of a Cove that 's Part of a Circle, as Fig. 19.

As all Coves are Parts of Arches, ſo all Angle Brackets muſt be Parts of their correſponding Groins; for Example, Suppoſe it was required to find the Angle for the Cove A, you muſt proceed (as in *Prob.* I.) as if you were to find the Groin of the whole Arch, and ſtrike the ſame Ellipſis, B B, and place it as you ſee in the Figure; then continue the Line C, (which limits the Progreſſion of the Cove) till it meets with the Tranſverſe Diameter of the elliptical Arch B B, and from thence raiſe the perpendicular Line D, and that will cut off juſt as much as will make the Angle Bracket B of the Cove A.

But if the Room be not ſquare, or the Sides not at right Angles one to the other, and it is not a great deal out of Square; you muſt draw the Plan of the Projection of the Cove according te the Angle of the Room, as the Figure B, and ſet off the Line A, from one End of the Ellipſis on the Tranſverſe Diameter, and from thence raiſe a Perpendicular, and that will cut off the Part required for your Angle Bracket, *Fig.* 20. And if it be very much out of Square you muſt draw the Plan of the whole Room, as the Figure 21, and ſet off the Diameter of the Circle that forms your Cove and draw Lines parallel to the Sides, as you ſee in the Figure, and take the Lines B and D for the Tranſverſe Diameters, and the Conjugate Diameters will be the Diameters of the Circle that form'd the Cove; then proceed as before directed.

N. B. This Method will do for Hexagons, Heptagons, or any right-lined Figure whatſoever.

PROBLEM VIII.

To find the Angle Bracket of an Elliptical Cove; Fig. 22; *whoſe tranſverſe Diameter is horizontal as the Cove,* B.

Square the horizontal Diameter of the Ellipſis that forms the Cove, and proceed as in *Prob.* VII to ſtrike out the Ellipſis, C D, then continue the Line E, till it meets with the Tranſverſe Diameter of the Ellipſis C D, and from thence raiſe a Perpendicular K, and that will cut off the Arch C, which will be the Angle Bracket required.

PROBLEM IX.

***To find the Angle Bracket of an Elliptical Cove, whoſe Conjugate Diameter is horizontal as the Cove.* Fig. 23.**

Square the Horizontal Diameter of the Ellipſis that forms the Cove K, and proceed as before taught, to ſtrike the Ellipſis R, T, then continue the Line O, till it meets with the Line D, and from thence raiſe the Perpendicular L, and that will cut off the Arch R, which will be the Angle Bracket required.

But here it is to be obſerv'd, that as in the foregoing Problem, the new Ellipſis that form'd the Angle Bracket became longer, here it may become ſhorter, for if the Diameter of the firſt Ellipſis be in the ſame Proportion as the Diagonal is to the Side of a Square, the Angle Bracket may be Part of a Circle; and if the firſt Ellipſis be a long one; the Diagonal Line D, will become the Conjugate Diameter of the new Ellipſis that is to form the Angle Bracket, by making the dotted Line E to form the Riſe of the two Diameters F and F to be equal.

N. B. I have thought proper to ſhorten the Directions of ſome of the Problems concerning Coves, becauſe the Method is exactly the ſame, and may be applied to any Cove that is Part of any Ellipſis, or Circle, take it out of what Part you pleaſe, for the Line of Projection being continued until it meet with the Diameter D, and from thence a Perpendicular being raiſed, it will cut the correſponding Part required, as you ſee in the above Figure, the Riſe being always conſider'd equal in both, and is made by a Line parallel to the Conjugate Diameter D.

CHAP. IV.

PROBLEM I.

To glew up the Crown of a Buffet, whoſe Front and Back are both Semicircles. Fig. 24.

THIS Sort are in moſt common Uſe, and are the eaſieſt to be conceiv'd; they are perform'd by the following Method. Take a thin Piece of Board for your Mold, which muſt be juſt Half the Semicircle, as the vacant Space D, in the Figure; divide this according to to the Thickneſs of your Stuff, as you ſee in the Figure, and let the Joints croſs each other in the Plan; then take the Line, *a*, for your firſt Center, the Line, *b*, for your ſecond, and ſo on till you have compleated the whole Crown, obſerving to ſet a Bevel to every Thickneſs, according as you find them on the Compaſs Edge of the Mould, and work the Pieces by the ſame, then glew them down one upon another, and that will form the Crown required.

To glew up the ſame in a different Manner proceed as before directed, and glew up three or four Rounds (as will ſuit your Deſign beſt) then take them off your Board and glew up the ſame Quantity, and ſo on till you have got enough for the whole Crown, then glew together in Parts. This Method is moſt proper when the Crown is not to be painted.

PROBLEM II.

To glew up the Crown of a Buffet, whoſe Front and Back are both Elliptical. Fig. 25.

To perform this you muſt have two Moulds one muſt be the Quarter of the Ellipſis B, the other a Quadrant, or Half a Semicircle, as the Space A, theſe you muſt divide according to the Thickneſs of your Stuff, then will the Lines on the Quadrant be Half the Conjugate Diameter, and the Lines on the Elliptical Mold will form be half the the Tranſverſe Diameter of all the Elliptical Pieces that form the Crown; that is the Line O, will be one Center, the Line, *a*, the other of the firſtPiece you glew on; and the next Lines, *viz.* *b*, *c*, will be the Centers of the neat Pieces,and ſo on: And the Quadrant Mould will give you thoſe at the Ends; then proceed as directed, *Prob*: I.

PROBLEM III.

To glew up the Crown of a Buffet, whoſe Front is a Semicircle and the Back elliptical. Fig. 26.

This Sort of Buffet is very often introduc'd where the Receſs that is to receive it is ſhallow, and not half ſo deep as it is wide.

The Method of performing it differs very little in Practice from the laſt, and the Difference is in the elliptical Mould, which in the former is on the Conjugate Diameter, and here you muſt divide on the Tranſverſe, as you ſee the Space G, is in the Figure; then begin with the Lines O, and A for the two firſt Centers, and proceed as before directed.

PRO-

PROBLEM IV.

To ſtrike out the Ribs of the Crown of a Buffet that is to be plaiſter'd, and is a Semicircle both Ways. Fig. 27.

This Sort of Buffets are often plaiſter'd when they are very large, and will admit of being enrich'd with Fruit, Flowers, a Shell, or any other Ornament, according to the Fancy of the Deſigner. Firſt, Strike out the Back Plate, and divide it into the Number of Ribs you deſign for the Crown, as the Figure D, and from the ſame Centers ſtrike out the Ribs which will be Quarters of Circles, and fix one End to the Back-Plate, and the other Ends muſt meet altogether in the Center of the Crown, and they will form the Crown required.

PROBLEM V.

To ſtrike out the Ribs of the Crown of a Buffet that is plaiſter'd, whoſe Front and Back are both elliptical. Fig. 28.

Firſt, Strike out the Back and Front, according to your Dimenſions, as before directed, and divide the Back into the Number of Ribs you deſign for the Crown, and from thence draw Lines to the Center, as you ſee in the Figure B, then take the Line O for one Center, and the Line *a* for the other, and ſtrike the Semi-Ellipſis C, and that cut into two at Z, (*Fig.* 29.) will be the two firſt Ribs next to the Front, then take the Line *b*, for the next longeſt Center to work with the Line O, (which being a fix'd Center to them all, muſt remain the ſame) and they will ſtrike the next two Ribs, and in like Manner proceed till you come to the Middle, O, which will be a Center of itſelf for the Middle Rib, then fix them in their proper Places, obſerving to let the Ends which are cut in ſunder, meet altogether in the Center of the Crown, and fix the other Ends to the Back Plate to follow one another as they were ſtruck out.

PROBLEM VI.

To ſtrike out the Ribs of a Buffet that is to be plaiſter'd, whoſe Back is elliptical and Front a Semicircle. Fig. 30.

The Method of performing this is nearly the ſame as the laſt, (*viz.*) firſt draw the Back and Front, then divide the Back according to the Crown; and from thence draw Lines to the Center, as you ſee in the Figure, then proceed as directed in the former Problem, *viz.* to take the whole Line O, for one Center, and the Line *a*, for the other, which will be a little ſhorter, and therefore will produce a Semi-Ellipſis nearly a Semicircle, which being cut in two will be two firſt Ribs next to the Front, then take the Line *b*, for the next Center to work with the Line O, which is the fix'd Center to them all) and that will ſtrike the next two Ribs, and ſo proceed on till you have compleated the whole Number, then fix them in their proper Places only obſerving that as in the laſt Problem the Ends where they cut in two went to the Crown, here they muſt be fix'd in the Back Plate, and they will form the Crown required.

PROB. VII.

To frame the Crown of a Buffet that is a Semicircle both ways. Fig. 31.

This Sort of Buffet is not very common, there being a great deal of Care and Trouble required to work them clean; by Reaſon the Mouldings muſt be ſtruck by Hand and moſt of the Plowing will be againſt the Grain; but thoſe that have a Mind to work one after this Manner may obſerve the following Method.

Firſt,

Firſt, Glew up the framing (as directed in *Prob.* I.) until you have enough for the Front Stile O, and likewiſe for the Spandrel Rails, *a*, *a*, *a*, *a*, which muſt diminiſh, as you ſee in the Figure, and be mortiſed into the Compaſs Place *e*, which muſt be worked by a Mould ſtruck from the Center as your Framing, and muſt be mortiſed into the lower Rails, *a*, *a*, whoſe lower Edge muſt be rebatted to receive the Back, then ſet off from your firſt Center, the Thickneſs of the Moulding you ſtick on the Framing, and that will ſtrike the Mould to work the Pannels by; which muſt be glew'd up by the ſame, ſo that the Joints may lie horizontal, or level as the Pannel D, in the Figure; for were you to make a Pannel never ſo thin, and think to bend it, you will be deceiv'd, for that will not form a regular Curve both Ways; therefore it is much the better Way to glew them up, as before directed.

PROBLEM VIII.

To Vinear the Crown of a Buffet in Goars that is a Semicircle both Ways. Fig. 32.

A Buffet finiſh'd after this Manner is alſo very uncommon, for I do not remember to have ſeen above two, and they are both in *Hampton*

Hampton Court Chapple; and (in my Opinion) have a very good Effect. And as it is natural to moſt Mechanicks, when they ſee any Thing uncommon perform'd in their own Way of Buſineſs, to have ſome Thought about the Method that was taken to perform it; therefore this Conſideration prevail'd with me ſo far as to recommend the following Method to perform the ſame.

Suppoſe the Semicircle D, to be the Back of a Buffet, you muſt divide it according to the Number of Goars you deſign, then draw the Line *a*, equal to the Semicircle D, and ſet off Half the Breadth of your Goar on each Side the middle Point *c*, and from thence raiſe a Perpendicular at Pleaſure as the Line *z*; then from the Half-Breadth of your Goar, *viz.* from the Point *a*, draw a Line to either End of the Line *a*, as the Line *o*, and from the Middle thereof raiſe a Perpendicular, as the Line *x*, and where that meets with the other Perpendicular *z*, will be the Center to ſtrike the Curve Line *n*, *n*, which will be one Side of the Goar; then perform the ſame on the other Side as *m*, *m*, for the other Side of the Goar; which being cut in two at *c*, will make two Vinears in the Shape required. And by the ſame Method you may ſtrike out all the reſt: then glew them down with the broad Ends towards the Back, and the piked Ends will all unite in the Center of the Crown.

N. B. This Method is very likely to do if the Goars are narrow, and the Vinears very thin, but if they exceed two Inches and a Half or three Inches at the Bottom, the ſafeſt Way will be to let the Vinears be thick enough to be work'd by a Mold (broadways) on the Backſide, and bend them longways only, and work the Inſide (after it is glew'd down.) And I am apt to believe that thoſe at *Hampton* Court were work'd after this Manner; for their Vinears ſeem'd to me to be ſix Inches at the Bottom, and for that Reaſon (I think) it impoſſible to be laid in a thin Vinear becauſe the Middle Line *a*, muſt become as long as the Curve Line *n*, *n*, otherwiſe it will not ſtick in the Middle. But let the Vinear's be broad or narrow, the Method I have here given will ſtrike out the Compaſs Line for the Edge. But when the Vinears are very narrow, the Difference between the middle ſtreight Line, and the Compaſs-Line on the Edge is ſo very little, it is poſſible that when the hot Glew comes upon it, it may ſtretch a little, and by that Means lie faſt.

As to the Directions I have given in this Problem, or any other that regards the working Part only, I muſt deſire the Practitioner to obſerve them as ſuch as I ſhould make uſe of myſelf; and not as poſitive or abſolute; for as ſeveral Men have different Ways of working the ſame Thing, it is probable they may find out better, but as the Theory is built on Demonſtration they may be ſafely relied on by thoſe that have Occaſion to make uſe of them.

PROBLEM IX.

To ſtrike out a Compaſs Soffite that is horizontal at the Crown, and ſplays at both Ends according to the Shutters. Fig. 33.

Firſt, Find the Center that ſtruck out the Head of the Arch by *Prob.* iii. *Chap.* II. then ſet off the Margin you intend to ſhew, and ſtrike the Edge of the Stile next to the Window-Frame; ſuppoſe the Arch D, all the other three will be elliptical, and may be found by the following Method.

Firſt, draw the Plan of the Soffite, as if it were to be a flat one, as you ſee in the Figure, *viz.* *a*, repreſents the Back Stile, and *e* the Front; then ſet off the Splay and draw the Line O*f*, and where that cuts the Stile Line, let fall a perpendicular Line to the Line, *b*, and they will give the Splay of the Stiles, and likewiſe the Pannell. Then take a Trammel and fix directly over the firſt Center, as you ſee in the Figure; then take the Rod that belongs to the Trammel, and fix the Pin next the Tooth or Pencil, to the firſt Center, E, and put in the upper Grove of the Trammel; then bring the Tooth or Pencil to the firſt Splay, *n*, and obſerving where the Rod croſſes the lower Grove of the Trammel, there fix the other Pin of the Rod, then will the Trammel be fix'd to ſtrike the firſt Splay *n*, and by the ſame Method ſtrike out all the other Splays. But if the Soffite be very flat Parts of a Circle will do inſtead of Elliptical Parts, and the Centers thereof may be found by *Prob.* iii. *Chap.* II.

N. B. As there are ſeveral Ways of Glewing up thoſe Sorts of Soffites, I have omitted giving any Directions here, and muſt refer the Reader (if he doth not know of any better) to thoſe I have already given in ſeveral of the foregoing Problems relating to Compaſs Work.

PROB.

PROBLEM X.

To find the Return of the Cornice of a Pediment. Fig. 34.

Draw out the Cornice according to the Angle of the Pediment, then raiſe a Perpendicular any where ſo as to interſect the Cornice, as the Line O, *Fig.* 1. and from that Line ſet off the Projection of the Cornice on a Level, and draw out theMembers as you ſee in the Fig.F and that will be the Return. But if your level Cornice be firſt given, and you want to find the Pediment or raking Part, draw out the level Cornice F, *Fig.* 1. and raiſe a perpendicular Line, as O, and from thence ſet off the Projection and return it as you ſee in the Figure; then draw the Lines of the Pediment Cornice, G, L, H, M, *&c.* according to the Angle of Interſection; and from a Line at right Angles give it's proper Return, as L; and that will be the Cornice required, and the Ogee which returns round the Modillion H. There are ſeveral other Caſes where Moldings require to be enlarg'd to make them a Quadier, that is to make all the Members meet, for if a Semicircle Molding meet with a ſtreight one, as the *Fig.* 35. and the Joint be a true Miter, at 3 the Compaſs Part will be larger than the ſtreight one. But if the Compaſs Part be the ſame Breadth as the ſtreight one, and the Members in the ſame Proportion, then will the Interſection form a crooked Joint, as *Fig.* 4; therefore in ſuch Caſes, as I have here deſcrib'd (if it is not to be a true Miter) I conceive the beſt Method is firſt to draw the Out-lines of both the Moldings of the ſame Width as in *Fig.* 5; and from their Interſection draw the Miter-line O, then draw the Members of the ſtreight Parts, and from where they interſect the Miter-line O, draw the Members of the Compaſs Part, and they will be in the ſame Proportion.

N. B. The Inſtructions I have here given relating to Moldings, I muſt own will be of little or no Service to a great many Workmen, they being very common in Practice and not very difficult to underſtand; but as I deſign this Book for general Uſe, this Problem may be uſeful to the younger Sort of Practitioners, and for that Reaſon I thought proper not to omit it.

PROB.

PROBLEM XI.

An Architrave being given as E 1*ſt, to draw another in the ſame Proportion as the Architraves* B *and* D, Fig. 36.

This depends on *Prob.* 4. *Chap.* II. where you are taught to divide a Line in the ſame Proportion as another given Line is divided. If you want a leſſer than the given one E 2d, ſet off your deſign'd Breadth from the Foot of E, at an Angle you pleaſe, and from the Diviſions of the given Architrave E, draw parallel Lines, as you ſee in the Figure, and that will divide the Architrave D, in the ſame Proportion. And by the ſame Method you may draw a larger one, as B, *Fig.* 37. and as all the Members are work'd down as far as they are work'd on the Thickneſs will be increaſed in the ſame Proportion, by obſerving to ſet off the firſt Facia the ſame Thickneſs as the Bead is to work on, which is given by the parallel Lines, and the Thickneſs of the Second Facia and the upper Ogee are found by the ſame Method, or the Thickneſs may be found by drawing parallel Lines, as the dotted Lines plainly ſhow.

PROBLEM XII.

To find the Length of the high Rafter of a Roof be it bevel or ſquare.

Firſt, On ſome convenient Floor, or large Drawing-Board, draw the Out-lines of the Building, according to the Angles, and let B, C, D, E, repreſent the Out-ſide of the Plate, *Fig.* 38; then from the ſquare End C, give the Roof its proper Pitch, and draw the Lines O, O, for the common Rafters, and divide the Line C, into as many Parts as the Building is Feet wide, and the laſt Diviſion, divide into twelve Parts for Ihches, and that will be a Scale to meaſure any Part of the Roof: Then draw the Middle-line repreſented by the dotted Line A, and draw the dotted Lines *p*, *p*, the ſame Diſtance from the Ends as the Line A, is from the Sides, and from the Points where theſe Lines interſect, or croſs each other, draw the Lines *d*, *d*, *d*, *d*, which will be the Projection of all the Hip Rafters, then take the dotted Line *m*, (which is the Height of the Pitch) and add to each of the Lines *d*, *d*, *d*, *d*, and from thence draw the Lines *b*, *b*, *b*, *b*, as you ſee in the Figure, and they will be the Hip Rafters of the whole Building. And if you want to find the Length of the ſhort Rafters make a right Angle Triangle, A, *Fig*. 39. and let the Hip *b*, be the Hypotheneuſe, the common Rafter C, the oppoſite Side, and the Baſe, Half the Breadth of the Building; which divide according to the Diſtance you intend for the Rafters, as you ſee in the Figure A, and apply them to the Scale; and that will give you the exact Length of any of them, and the Figure will give the Bevel of the upper Ends.

The Bevel or Back of the Hip-Rafter may be found by dividing the Hip with a Line down the Middle, after 'tis cut off to its proper Angle, and from that Line as a Diagonal ſet off the Angle of each Corner of the Building, and that will give you the Bevel.

N. B. This Problem depends on the Nature of all right-lin'd Figures, in which if the Meaſure of any one Part be known, it will meaſure all the Reſt.

PROBLEM XIII.

To find the Hip or Angle Rafter of a Roof whoſe Plan is an Octagon or Hexagon. Fig. 40.

Firſt, Draw the Plan of the Building as large as you can with Conveniency, and from the Middle of one Side, draw the Line O, to the

Center,

Center, and from one of the Angles draw the Line, Z, which will be the Line of Projection of the Angle Rafter, and, O, will be the Line of Projection of the Side Rafter, then take the Line, *a*, the Height you intend for the Roof, and ſet off at Right Angles, from one End of the Line, O, and Z, and draw the Lines *b*, *d*, to the Center, as you ſee in the Figure, and they will be the two Rafters; that is, *b*, will be the Side Rafter, and, *d*, the Hip or Angle Rafter. And if you would know the Lengths of the ſhort Rafters; make a Triangle, as, A *Fig.* 41. and let the Baſe be equal to one Side of the Octagon, Hexagon, *&c.* and the Sides equal to the Line *d*, and divide the Baſe, according to the Diſtance of the Rafters, and draw parallel Lines, as you ſee in the Figure; then make a Scale of the whole Breadth of the Building, (or any known Part) and that will give you the Length of any Part thereof.

PROBLEM XIV.

To find the Hip Rafter of an Ogee Roof. Fig. 42.

Theſe Sort of Roofs are very ſeldom made uſe of, unleſs it be for a Summer-Houſe, or ſome ſmall regular Building, whoſe Plan is a Square, a Hexagon, or ſome ſuch even ſided Figure.

Suppoſe, the Plan a Square, as in *Fig.* 41, firſt ſet out in the Middle of the Plan, the Square of the Necking you intend to have at the Top, and from thence draw the Lines *a*, *a*, which are the Lines of Projection of both Rafters, then from either End at right Angles draw the Lines O, O, for the Height of the Roof, and they will give you the Length of both the Rafters, which are repreſented by the dotted Lines, Z, Z, and from theſe you muſt ſtrike the Ogees of both Rafters, as you ſee in the Figure; that is the Side Rafter muſt be ſtruck from two Centers after the Common Method of ſtriking an Ogee; but the Angle or Hip Rafter (if you have a Mind to be very exact) muſt be ſtruck with a Trammel or String; for as all Ogees are Parts of Cylinders, their Miters will be elliptical; therefore the Hip Rafter muſt be conſider'd as the Angle Bracket of a Cove, whoſe Centers may be found, by *Chap.* III. *Prob.* iv. that is, take the Diameter of the Circle that form'd the Ogee of the Side Rafters, for the Conjugate Diameter, and the Diagonal of that Line ſquar'd, for the Tranſverſe: and ſtrike them out as the Figure directs, and that will be the Shape of the Hip Rafter exactly.

But as the Difference between an Ogee Hip ſtruck from an Ellipſis, and one ſtruck from a Circle is ſo very ſmall, they may both be ſtruck out the common Way for any common Buſineſs. And as all the Side Rafters, excepting one, will be but Parts of Ogees, they are to be conſider'd as if they were whole, and a certain Part cut off at the upper End, as the *Fig.* 43. A will direct, that is to take the ſhorteſt Line, *a*, in *Fig.* 42, for the Baſe of the Triangle A, then take the ſhorteſt Line Z, and ſet off at right Angles from the End of the Line, *a*, and let the longeſt Line, Z, be the Hypothenuſe, as in the Figure, and divide the Line, *a*, according to the Diſtance of the Rafters, then draw the Line *e*, equal, and parallel to the Line, *a*, and divide it into the ſame Number of Parts, and draw the Ogees, as you ſee in the Figure. And where the Miter Ogee, *z*, interſects the other, they muſt be cut off, and the lower Parts will be the Short Rafters, then make a Scale of any known Part of the Building, as directed *Prob.* xii. of this Chapter) and that will give you the Length of any Part of your Roof. As to the Back, or Bevel, of the Hip Rafter it may be found as before directed.

N.B. There are ſeveral other Sorts of Roofs beſides thoſe I have here given, which are often

ten uſed in Building, but as they depend on the ſame Theory, or at leaſt on ſome of the foregoing Problems, I think it would be of little Uſe to give any more Examples here, for if the Theory of thoſe I have already given, are rightly underſtood, it will naturally lead the Practitioner to find the Rafter, or any other Part of any Roof, let the Shape be what it will.

PROBLEM XV.

To ſtrike out the Ribs of a Scalene Coue, applied to the Top of a Malt Kilu. Fig. 44.

This Contrivance is very often made uſe of in the Country to carry off the Smoak, and ſteam off the Malt when its drying, and erected much after the Manner of the Figure B, the conical Part, A, is fixed on a Center to turn with the *Wind*, over the Figure B, which is a large round Funnel built directly over the Middle of the Malt Kiln. As to the Method of erecting the lower Part, B, I ſhall leave it to the Practitioner's own Judgment. But as the Top is a Mathematical Fignre it muſt require the Knowledge of Lines to perform it as it ſhould be, therefore I ſhall give a ſhort Demonſtration of the Figure A, by itſelf. This

Figure if continued quite round, to cover the whole Funnel B, and terminated in a Point at the Top, would be an elliptical Scalene Cone, but there being a Bit wanting at the Top, it can only be the Fruſtrum of ſuch a Cone, that muſt have a Part left open, as E, to let out the Smoak. The Reaſon why 'tis elliptical is becauſe the Baſe, or Bottom, is oblig'd to be a Circle, otherwiſe it would not turn round, therefore the Ribs ought to be elliptical, and plac'd at right Angles with the Axis, or Middle Line O, which will be the ſtrongeſt Way and ſooneſt perform'd; for if they are put horizontal, as the dotted Lines, *b*, *b*, *b*, *b*, *Fig.* 45. which is the common Way; they will all be Circles. But then there is a great deal of Trouble to work them bevel, according to the back Line K; therefore to make them elliptical, will ſave moſt of that Trouble, and they may be ſtruck out by the following Method.

Firſt, Divide the Cone A, into what Number of Ribs you pleaſe, as they are repreſented by the Lines *u*, *u*, *u*, *u*, then ſet off the Space you intend to leave for the Smoak, as the Line E, then from the ſame Baſe, draw the Fruſtrum of the upright Cone, D, *Fig.* 46. and divide it into the ſame Number of Ribs parallel to the Baſe, then to ſtrike out the firſt Rib take the Line *n*, in the Figure D, for the Tranſverſe Diameter of the Ellipſis, *Fig*. 47. And the Line *u*, next the Baſe in *Fig*. A. for the Conjugate Diameter, and proceed to ſtrike out the Ellipſis, as directed *Chap*. II. Then take the ſecond Line *u*, next the Baſe, for the Coujugate Diameter of the Second Rib, and diminiſh the Tranſverſe in the ſame Proportion, that is let the Center Pins of your Trammel remain the ſame Diſtance one from the other, as before, and ſtrike the Ellipſis *a*, *a*, *Fig*. 47. which will be the Second Rib; and by the ſame Method ſtrike out the Reſt, as the *Fig*. D, will direct, and as to that Part of the Ellipſis, which will be for Uſe, they may be diſcover'd by cutting off as much of every Conjugate Diameter of the Ellipſis, as the Line E, in *Fig*. 44, cuts off from each Rib, and as the dotted Lines *Fig*. 47 directs.

PROBLEM XVI.

To ſtrike out a Saſh and Frame, with a circular Head and Front, for a circular Building, with Directions how to work the ſame. Fig. 48.

Theſe Sorts of Windows are not very often made uſe of in Building, but where the Founder doth not value the Expence, and if they are well introduc'd, they muſt certainly appear with a noble Grandeur, and render a Building very magnificent. It muſt be allowed, that ſuch a Piece of Work is very difficult to perform, and muſt require a good Hand, that hath been us'd to Compaſs Work to undertake it. But was I to perform the ſame, I ſhould proceed in the following Manner.

Firſt, To find the Center of the circular Part of the Building, and draw the Plan of the Saſh Frame, B, which is repreſented by the Sill D, then make three Molds, one to the Inſide of the Saſh-Frame, another for the Inſide of the lower Saſh, and the third for the Inſide of the upper Saſh; then glew up a Board by the firſt Mold, as large as the whole Frame, and there on the Convex Side draw out the whole Saſh and Frame, as may be ſuppos'd like the Figure 49, G. But here it is to be obſerv'd, that in drawing out the circular Head of the Saſh and Frame, if the Center was a Semicircle that turn'd the Arch in the Building, it will not be ſo on the Compaſs-Board you draw on, for if you endeavour with a Pair of Compaſſes, from one Point, to ſtrike a Circle on a Cylinder, it will be an Ellipſis in Plano, and from the ſame Reaſon an Ellipſis may be ſo proportion'd, as to be a Circle when taken off the

Cylinder, which may eaſily be done, by covering it with Paper and taking it off when ſtruck out, and laying it on the Plane. From hence 'tis plain, that the Lines for the Head of the Window G, when drawn on a Compaſs-Board that is Part of a Cylinder cannot be ſtruck from one Center, but muſt be elliptical, whoſe Diameters may be found by Girting over the Compaſs Board with a Line, as far as the Width of the Saſh Frames, and that will be the Tranſverſe Diameter repreſented by the Lines, O, O, in the Figure G, that Line muſt be laid down on a plain Board, then take the Line, *á*, in the Figure, *n Fig.* 50. for the Conjugate, and place it at right Angles from the Middle, and by *Prob.* vii. *Chap.* III. find out the Center to ſtrike the Ellipſis with a String, and ſet off thoſe two Centers on the Line O, O, in Figure G, and there fix two Nails and with a String ſtrike out the Arch *m*, and by ſetting off proper Margins, the whole Head of the Saſh and Frame, may be ſtruck out by the ſame Center. This being done, compleat the whole Window by drawing every Part in its full Proportion.

Then begin to work the Head of the Saſh Frame, by fitting of ſolid Pieces (that are thick enough and wide enough for the Head of the

Frame, Beads included) ſo as to make a Joint to the Compaſs-Board, or Mould, you work on, according as the Lines direct; and from the under Side ſo fitted, gauge them to their proper Thickneſs, and mortiſe and tenent them together (as you ſee in the Figure) according to the Number of Pieces, obſerving to let the ſolid Part come low enough to receive the Pully-Pieces and Frames, which may be let in Fluſh, and nail'd to the ſame. The Head being thus prepar'd and pin'd together, lay it down on the Board where it was firſt fitted, and fix a Piece of Wood of the ſame Thickneſs over the Centers at *n*, and transfer thoſe Centers before given to the Top of the Piece ſo fix'd, and let them be a ſmall Matter wider aſunder, by Reaſon this upper Side of the Saſh Frame muſt be wider than the lower Side, to anſwer the Splay of the Pully-pieces, which ought to point to the Center of the Building, according to the firſt Figure D. The Head of the Frame being work'd according to the given Arch; gauge off the Beads; rebate the Space between (which is the Thickneſs of the two Saſhes,) and ſtick the Beads, and the Head will fit the Arch propos'd.

The other Part of the Frame being not very difficult to perform, needs no Direction here therefore the next Thing I ſhould do, would be, to take the ſecond Mould (which is the Inſide of the lower Saſh) and fix the Compaſs Board to the ſame, by ſetting it a little wider with two Braces underneath, untill it become flat enough to fit the Mold. It being thus fix'd begin the lower Saſh, which may be bent (if the Curve is not too quick) in three Parts, after the common Way of performing ſuch Work the upper Saſh may be work'd after the ſame Manner, (when the Compaſs Board is ſet to the third Mould as before directed) excepting the Semicircle Part, whoſe Curves being of a Compound Nature cannot be bent in Thickneſſes, therefore I ſhould chuſe to bed the Rail and Spandrels after the Manner as before directed for the Head of the Saſh Frame.

CHAP. V.

Of the Nature and Properties of Arches, ſhewing what Shape are moſt durable, and capable of ſupporting the greateſt Weight, with ſome Remarks on the intended New Bridge *at* Weſtminſter.

BY the Word *Arch*, we are taught to conceive the Idea of ſome regular Curve, or crooked Line, as the Line, A, *Fig*. 51. which when applied to Practice in Building is always put with the Convex Side uppermoſt in order to ſupport ſome Weight, as the Fig. D. But without the Butments, *e*, *e*; (if it was in Parts as Building requires) it would not ſupport itſelf, for the Action of Gravity preſſing upon it, would ſoon tumble it down: And was it a flexible or malleable Body, would ſoon reduce it to a ſtreight Line.

From hence 'tis plain, that the Strength of all Arches depends upon the Butments, and that

Dependency is in Proportion to the Height they riſe from the Chord Line of their reſpective Arches, which Line is repreſented by the Line A, in *Fig*. D.

The Truth of this will very plainly appear by ſetting up two Sticks (or Pieces of Wood in the Shape of Leavers) one againſt the other on a Plain Board, in the Nature of a Pediment, as the Lines *o*, *o*, *Fig*. 52. and *a*, *a*, *Fig*. 53. in the Arches, A and B. I ſay, the Pediment *o*, *o*, requires a greater Weight, or reſiſting Power, to be plac'd at the Foot *e*, *e*, to keep it from falling, than the Pediment *a*, *a*, therefore the Arch B, will conſequently ſupport a greater Weight than the Arch A, if their Butments are equal. The Reaſon of it is the Lines *a*, *a*, are nearer a Perpendicular than the Lines *o*, *o*, for if thoſe before mention'd Pieces of Wood, were plac'd perpendicular one againſt the other, with a Hinge at the Top, and Wheels put in the Bottom for the Sake of Experiment to take off the Friction; they would in that Poſition, want no Butment to keep them together at Bottom, but if they are a ſmall Space aſunder at the Bottom, they will want a Butment to keep them in that Poſition, otherwiſe they will run one from the other, and the further they recede from each other, the greater muſt the reſiſting Power, or Butment be, to keep them from falling.

From what hath been ſaid it appears, that Gravity acts on thoſe two Leavers, according as they are elevated or depreſs'd; and if ſo it muſt be in ſome Proportion; which Proportion may very nearly be determin'd by the following Figure G, *Fig.* 55. whoſe Theory depends on that of the Steel Yard; which for the better Underſtanding of what is to follow, I ſhall endeavour to explain, by the next *Fig.* 54. E. Let the Line *c* and *o*, repreſent the Beam, and *o*, the Center of a Pair of Steel-Yards, and ſuppoſe two Weights, as, *n*, and *r*, were to be hung at equal Diſtance from the Center, O, and the other Part of the Beam cut off, they would then hang in Equilibrio, that is, *n* and *r*, would be equal. But if the other Part of the Beam was to be added, and the Weight *n*, was carried on the Beam, as far as the Figure 10, and ſuppoſe the Weight was but one Pound each, then I ſay that the Weight *r*, muſt have Nine Pounds added to it to make it ballance the Weight *n*, when remov'd ſo far from the Center. But here 'tis neceſſary to obſerve, that in making thoſe Inſtruments, the Weight that is occaſion'd by the Length of the Beam is always accounted ed for before they begin to divide, and 'tis very eaſy to diſcover what Weight did belong to a Pair of Steeliards, ſuppoſing it to be loſt) by taking the Diſtance between the Centers of the Hooks, that is between O, and *r*, and apply it to the proper Edge, and the Diviſion there will tell you what the Weight ſhould be, for it is that Diſtance multiplied into the whole Length, as you may ſee in the Figure. But here in this preſent Caſe the Beam is only imaginary, for it is the Diſtance from the Center, that Occaſions all thoſe different Gravitations, for if we ſuppoſe the Circle, *a*, *b*, *c*, *d*, to be a Wheel, and, *o*, its Center, and a Weight of one Pound to be fix'd at its Periphery at *b*, and the Wheel to be turn'd round, the Weight when it is got to *e*, it will be 3 Pounds, and at Z 5; and the Gravitation of ſuch a Weight will increaſe in the ſame Proportion, as if it was carried along the Beam, *e*, as you may ſee by the Diviſions. By this uſeful Inſtrument may alſo be diſcover'd the Power of the Leaver from a Perpendicular to a horizontal Poſition, and may very juſtly be call'd a Scale to meaſure all mechanick Powers that act from Centers, and notwithſtanding our preſent Subject be two Leavers ſet up one againſt another, yet I believe the next Figure will make it appear very plain, that they alſo depend on the ſame Theory, and are ſubject to the ſame Laws of Gravitation. For as thoſe two Leavers, *a*, *a*, in *Fig*. 55. G. ſupport one another at the Top, and prevent their falling or acting like Leavers; yet, I conceive that Gravity will act on the Bottoms (when the Friction is taken off by Wheels) in the ſame Proportion, as if they were turn'd End for End, according to the Left Hand Side of the Figure G, when turn'd upſide down, that is to put the confin'd End downwards, and let the upper Ends fall one from the other. I ſay in the Fall of ſuch a Leaver, the Gravitation would be increas'd in the ſame Proportion as is there ſet down. For if the Leaver *a*, by falling from the perpendicular Line G, ſhould have gain'd a Force of one Pound, it would at *e* have gain'd three Pounds at *z* 5, and ſo on in Proportion, as was gain'd by the Weight at the Periphery of the Wheel in *Fig*. E, until it becomes horizontal. In the ſame Proportion I conceive Gravity to act at the Bottom of the two Leavers *a*, *a*, that is, if at *a*, they ſhould want a Butment of one Pound at each Foot to keep them in their Poſition; at *e* they would want three, and at *z* 5, and ſo on in the ſame Proportion as they are ſet down in the Right Hand

Side of the Figure G, until they become ſo far extended as to lie level on the Plane they moved on; from what hath been demonſtrated from *Fig.* G, it is plain that Gravity acts on Pediments, according as their Sides are elevated or depreſs'd: And if ſo it muſt certainly act on all Arches in the ſame Proportion, as their inſcrib'd Pediments are to one another in Reſpect to their Height. And from hence may be diſcover'd how much Weight one Arch will bear more than another, that is the ſame Width, and hath the ſame Butments to ſupport it. That is, if the lower Arch, in *Fig.* D. 56. will bear 500 Pound Weight, the Arch *a*, will bear 600, and the Arch *b* 700, and ſo on according to what Height you riſe; may the Weight be increas'd, which will always be in Proportion as the Sides of the inſcrib'd Pediments are to one another, when their Chord Lines, or Widths, are the ſame, as you ſee in the Figure.

Notwithſtanding I have given this Method to ſhew how much one Arch will bear more than another of the ſame Width and Butments, yet I do not pretend to know, how much Weight any Arch will bear, for there is no Arch that I know of, that can be ſaid to bear all the Weight that is built perpendicular over it; becauſe that Part hath Communication with Reſt of the Building, and cemented to it in ſuch a Manner that takes off a conſiderable Part of the Weight that would otherwiſe preſs upon it, if that Communication was deſtroy'd. And I may venture to ſay, that it is from this Reaſon, that Arches ſometimes become ſo looſe that their Key Stones are almoſt ready to drop, for Want of a ſufficient Weight, to keep their Parts together.

From this Obſervation it is plain, that all Arches want a Weight proportionable to the Height they riſe to keep their Parts firm in the Situation they are firſt plac'd, for it is very reaſonable to think that the Arches of *London* Bridge would not have remain'd ſo intire to this Day, if it was not for the Weight of Houſes that are erected thereon, which muſt certainly prevent thoſe frequent Shocks and Shakings that it muſt otherwiſe have ſuffer'd by loaded Carts and Carrs, and other Vehicles of Burden that daily paſs and repaſs thereon.

But whether the intended New Bridge is to have any ſuch, I know not, or whether the Ground Rents of ſuch Houſes would be equivalent to the Expence of making the Bridge ſo much the wider, I will not pretend to determine altho' I believe, that the Revenues ariſing from thence would be very conſiderable.

But to proceed, to make ſome Obſervations on the Shape of Arches, in Reſpect to their Duration.

I think the moſt common Sort that are to be found amongſt our Modern Buildings are either Semicircles, Segments, or Semi-Ellipſis, which I muſt own have an agreeable Effect on the Eye, becauſe they are Part of Regular Figures, and make a good Appearance in a Building, if they are well proportion'd, and well introduc'd, but this is not always obſerved by our Modern Builders, for I have often ſeen a Paſſage of three Foot wide with a Semicircle Arch, and a Gateway of ten, with an elliptical one, whoſe Height from the Springing hath not exceeded twenty Inches; ſuch a one cannot be ſuppoſed to be of any long Duration, without very ſtrong Abutments, unleſs the Weight be diſcharged by a concealed *Breaſt-ſummer*, or very little laid thereon. In ſuch Caſes, Ornament is conſulted more than Strength for the Arch of three Foot being a Semicircle will bear above ten Times more Weight than the elliptical one of ten Feet, with the ſame Butments by Reaſon of its Flatneſs, and double

Centers, which muſt render it very weak and unfit to ſupport a great Burthen. I mean ſuch Ellipſis whoſe tranſverſe Diameter is plac'd horizontal, as B, *Fig.* 57. but if you take an Ellipſis the other Way for an Arch, and let the Conjugate Diameter be horizontal, as A, then it will become altogether as ſtrong, and may very juſtly be eſteem'd the beſt Sort to ſupport a great Burthen, excepting thoſe formed by the Catenarian, which I ſhall endeavour to prove (before I leave this Subject) the ſtrongeſt of all and moſt durable. But for the Truth of what I have aſſerted in reſpect to the elliptical Arches *A* and *B*, I muſt refer the Reader to a very eaſy and familiar Experiment, which is to take an Egg (whoſe Shape is near enough for the Purpoſe) and try whether it will not bear a great deal more Weight on the Ends than it will on the Sides before it burſt, ſuch an Experiment ſeems to me to put this Matter out of the Reach of Contradiction, and will juſtify the Theory that I have hitherto endeavour'd to explain. Namely, that all Arches will bear a Weight proportionable to theHeight they riſe from their Springing, if their Chord Lines, or Openings, are the ſame, let the Shape be what it will altho' it muſt be allow'd that ſome Sort of Shape will bear more Weight than another of the ſame Height and Butments, for if the elliptical Arch B was a Segment of a Circle of the ſame Height, it would add much to its Strength by Reaſon that Curve would be more uniform and approach nearer to a Catenarian than it was before in that flat elliptical Form, for it is my Opinion, that the Strength of all Arches would be increaſed the nearer they approach that firm Arch of Nature, for ſo I muſt call it, by Reaſon it is form'd by Action of Gravity, which muſt be allow'd to be a natural Cauſe.

This Curve, or Arch, may be diſcover'd by ſuſpending a Chain, or flexible Line (that is not very light) from two horizontal Points, or Nails, as *o*, *o*, in *Fig.* 58 D, the Curve, or Arch, that ſuch a Line, or Chain, will form, is call'd a Catenarian, repreſented by the Line *a*. This Line, as I before obſerv'd, is form'd by the Action of Gravity, which acts on all Bodies, according to their Denſity, or Quantity, of Matter they contain, if their Form and Shape are the ſame; therefore, if Gravity by its Action on a ſlack Line, or Chain, forms the Arch *a*, it is very plain, that if it were turn'd upſide down it would form the Arch K, which conſequently muſt reſiſt that Action in the ſame Proportion, as the other gave Way, that is K would become an Arch of equal Strength in all its Parts, and for that Reaſon muſt certainly be the beſt Shape for any Arch that is to bear a great Burthen.

But, as the Properties of the Catenarian Arches are ſo far conceal'd that it would be very difficult to aſſign any Centers that would ſtrike the ſame, for if they are very flat they appear like Segments of large Circles, but if you endeavour to form a Semicircle by letting the Line drop half its Opening, it will then appear elliptical, and as you drop it lower it ſeems to approach the Hyperbola, ſo that the diſtant Appearances it makes in theſe different Stations muſt render it very difficult to find out proper Centers to ſtrike them out.

But for thoſe that have Occaſion to apply them to Practice may obſerve the following Method, and may anſwer the Purpoſe very well, if it be carefully obſerv'd, that it is to take ſuch a Line (as beforemention'd) and rub it with Chalk, or Charcoal, until it be fit to leave an Impreſſion then on ſome flat Plain or Board (that is large enough for the Uſe) fix in two Nails horizontally, according to the Width of your Arch, and from thence let the Line fall as far below the horixontal Line *a*, in *Fig.* G. 59. as you would have the Arch to riſe above it, then carefully preſs the Line hard enough to leave the Impreſſion, and that will be the Arch required as *n*, then move the Nails from *o* to K, according to the Margin you intend to ſhow in the Front, and from them let fall the Arch *m*, and that will limit the Border, or Margin, which may be divided and Mould made to fit the Curve in the ſame Manner, as if the Arch was in any other Form, as you may ſee in the Figure, which in Practice muſt be turn'd upſide down; but, as I obſerved before, that the lower the Line was let fall the nearer it approach'd an Hyperbola, therefore it cannot be expected that the Lines *n*, and *m*, will be parallel or appear concentrick like Arches ſtruck from the ſame Center, but for thoſe that ſhould think it appeared diſagreeable for the Margin of an Arch to be wider at Top, as *Fig*. G. may eaſily prevent it by making the Moulds parallel to the inward Arch *n*, which would be a Matter of Indifference in reſpect to its Strength.

But notwithſtanding all thoſe diſtant Appearances before-mention'd that are made by the Catenarian Line, yet I cannot help thinking, but that they are all of the Hyperbola Kind; for as the Hyperbola is that Section of a Cone cut any where when parallel to its Axis, I ſay it is no hard Matter to imagine a Cone large enough that will admit of the flatteſt, as well as the higheſt Arches to be cut off by ſuch a Section; now, I believe it will appear from what I have already ſaid on this Subject, that Catenarian Arches are the beſt Shape for Duration, and for that Reaſon the moſt proper Form for the New Bridge on the River *Thames*, if it be built with Stone. But be it as it will, I think the Foundation ought to be of Stone, as far as High Water Mark, and conſidering the Depth of the River muſt require ſome Contrivance to lay the lower Stones, and fix a Baſement in Water firm enough to ſupport ſo heavy a Weight that muſt conſequently depend thereon.

As to the Laying the Foundation, which is commonly built in Coffer-Dams, and which are carried to their proper Places in the River, and the Foundation there begun, and carried on in thoſe, obſerving as the Foundation ſinks to make good their Out-Work, to keep out the Water, and ſo work on untill the Pier is got above the Surface of the Water. This Method is practic'd abroad, where Buildings of this Nature are more common, and may do very well where the Piers are ſmall: But I cannot apprehend how ſuch a Method can be practic'd with a good Effect in the River *Thames*, where the Tide is conſtantly ebbing and flowing, and the Piers very large and heavy; neither am I able to conceive how a Foundation of that Nature can be well laid and ſecured where the Workmen have not firm Ground to work on, but altho' I cannot foreſee the good Effect of ſuch a Proceeding. This Method may be practicable, and may (for ought I know) be the only one intended to execute the Deſign of the Bridge. But if it be ſo determin'd, I hope it will be no Affront to thoſe Gentlemen concern'd, if I offer another that (according to my Notion of Things of this Nature,) will do as well, if not better, if it it be not thought too expenſive, which is to circumſcribe the Place in the River where the Piers are to ſtand with the Piles and Planks duff-tailed and grooved together and ſharpened and well ſhod with Iron fit to drive into the Bottom of the River in the Form of the Plan B, *Fig.* 60. the Length of thoſe Piles and Planks muſt be determin'd by the Depth of the Water, allowing for that Part that is to go into the Foundation. The Subſtance of the Piles ought to be ſubſtantial. The Thickneſs of the Plank about 6 or 8 Inches, and the Piles to be drove in about four Foot aſunder, and the Planks between, and ſo on till the whole Range be compleated. Such a Range of Piles and Planks may be too weak to reſiſt the external Preſſure of the Water, and if ſo, they may eaſily be ſtrengthened by driving in other Piles along the Outſide, about four or five Foot from ſome of the others that belong to the Range, and brace them with diagonal Braces, and that will be a Security againſt the external Water and prevent it, puſhing it down when the internal Water is all pump'd out. And if the Grooves (which ought not to go ſtiff) were dreſs'd with Greaſe, or Tar, or ſome ſuch Matter, it will make them drive the better, and be a Means to prevent their Leaking, not as it can be ſuppoſed that ſuch a Fence will be without any. But I cannot apprehend, that there will be any Leaks ſo large, or numerous, but they may be diſcharged by Chain Pumps, and the Place kept dry enough for the Workman to lay the Foundation, as well as if there was no River to interrupt them: This Method ſeems to me to be more agreeable to the Nature of the Deſign, than the former one before mention'd; but as I can give no Precedent of any Proceedings of this Nature, I muſt leave the Publick to judge of the Effect. At the Place where the Bridge is to croſs the River, Care ought to be taken, that it be where the Stream hath a direct Courſe, and the Bridge to be built at right Angles to the Stream, otherwiſe it will render the Paſſage for Boats and Barges more dangerous and difficult to paſs and repaſs than if the Stream run parallel to the Sides of the Arches.

This I muſt own is a plain Obſervation, but very neceſſary to be obſerv'd by thoſe that are intruſted to ſet out the Place where the Bridge is to croſs the River.

Here I intended to have finiſh'd this Subject, but ſeeing two Pamphlets publiſh'd, the one being a Deſign for the Bridge, the other a Reply to Mr. *James's Review*, by which I am inform'd, that not only one Mr. *Langly*, but ſeveral ingenious Gentlemen have ſome Time ago publiſh'd their Deſigns and Calculations relating to this new intended Bridge, which had I known before (it is very probable) would have prevented my ſaying any Thing about it. But as their Views in publiſhing ſeem different from mine, and I have unwarily enter'd upon this Subject, I ſhall venture to go on with it a little further, not as I would willingly enter into that Controverſy that hath been ſo warmly diſputed amongſt thoſe that would have their Schemes perform'd. But what I intend only to make ſome few Remarks on what I have ſeen, which will render the Subject on Arches the more compleat, and may chance to give this Performance a better Taſte to the Publick.

Mr. *Langley*, in the Beginning of his Deſign for the Bridge, hath taken a great deal of Pains to eſtimate the Fall of Water that will be occaſion'd by a Bridge being built over the River *Thames*, either at the *Horſe Ferry*, or at *New Palace Yard*, and in his Reply to Mr. *James* hath beſtow'd ſeveral Pages in the Vindication thereof.

But, ſuppoſing this new intended Bridge ſhould occaſion a Fall of Water that will be an Inch or two more or leſs than Mr. *Langley* would have it to be, or that it will be High Water between the two Bridges before it is above the New One, ſeems to me to be a Matter of no Conſequence, ſince it muſt be allow'd by all that know any Thing of the Matter, that the New Bridge will not occaſion any material Difference in the Height of the Tides in general, but that they will flow to the ſame Height as uſual.

I think ſuch Niceties as thoſe may be conſider'd but as Trifles in Reſpect to the principal Deſign, which is to erect a Bridge over the River in the moſt expeditious Manner and to be both convenient and durable, how far theſe Deſigns and Direction propos'd by Mr. *Langley* and others are likely to anſwer the End, I ſhall not venture to enquire.

As my chief Deſign is to demonſtrate the Nature and Property of Arches. I ſhall begin my Remarks on theſe deſign'd by Mr. *Langly*, which being of the Catenarian Kind (as I have before obſerv'd) are the ſtrongeſt of all other, and for that Reaſon, the moſt proper to apply to a New Bridge over the River of *Thames* if they are well proportion'd, and had Mr. *Langly* but deſign'd them lower or laid a greater Weight (or Thickneſs) on the Crowns of thoſe he hath there given, I ſhould have thought it more conſiſtent with the Nature and Property of ſuch Arches whoſe Height is more than half their Opening, for it hath before (in *p.* 49.) been demonſtrated that all Arches will bear a Weight (on their Crowns) proportionable to the Height they riſe, if their Abutments are the ſame, and if they will bear it, it is plain they want it from the following Obſervation that may be made of a common Tub or drinking Veſſel which may very juſtly be ſaid to have the ſame Properties of an Arch, for the Staves may be conſider'd as ſo many Stones whoſe Joint Point to one common Center, and the Hoops that circumſcribe them as their Weight or Preſſure then I think it cannot be deny'd by any Perſon (of common Underſtanding) that the tighter thoſe Hoopes are drove on round ſuch a Veſſel the more compact it muſt keep the Staves and the ſtronger the Veſſel will be for ſuch a Weight or Preſſure therefore it appears to me, that Weight on an Arch will have the ſame Effect as a Hoop hath on a Tub if the Weight be well proportion'd.

But in order to give my Opinion in this Affair the Actions of Gravity on ſolid Bodies ought to be underſtood and the Shape of the Arch well conſider'd before a Man can form any Judgment about the Weight it will carry, or on what Part to beſtow it to the beſt Advantage, therefore for the better underſtanding what is to follow on this Subject. I ſhall venture to lay down the following Theorems,

I. When any Weight preſſes on the Sides or Haunches of an Arch the Weight on the Crown muſt be conſider'd as an Abutment to that Weight on the Haunches and in Proportion to the Height they riſe from the Cord Lines of their reſpective Segments, will the Weight on the Crown be required.

II. And as the Weight on the Crown is an Abutment to the Weight on the Haunches ſo is the Weight on the Haunches an Abutment to the Weight on the Crown.

III. And as the Weight on the the Haunches wants to reduce the Curvature thereof to a ſtraight Line, contrary to that, doth the Weight on the Crown want to make it riſe higher or puſh it out at Foot if there is no Abutment plac'd there to prevent it, and both would produce that Effect if it was not for a Counter-Ballance of Power as will be beſt explain'd by the following Figure.

As I have *p.*53. propos'd a Method in order to diſcover how much Weight one Arch will bear more than another that hath the ſame Extent and with the ſame Abutments, I ſhall here conſider what Effect the Weight on the Haunches hath on Arches of different Shape, this Method is built on the ſame Theory as the Former and to ſave the Reader the Trouble of turning back (as the Figure is nearly the ſame) I ſhall explain it thus:

If the Segment Arch, *a*, *e*, *e*, fig. 61. will bear 5 Hundred (or a Tun) Weight the Semi-circle, *a*, *b*, *c*, will bear 6 Hundred with the ſame Abutments, and the Cartinarian *a*, *d*, *c*, will bear the Weight in reſpect to the Abutments below but if they are both conſider'd as having no Weight on their Haunches, the Cartinarian muſt be the ſtrongeſt, by reaſon of the Curvature of its Haunches are nearer a right Line than thoſe of the Semi-circle for was there as much Weight laid on the Crown of the Catenarian Arch as it would juſt bear the ſame Weight if apply'd to the Semi-circle would occaſion it to burſt out and fall down, which plainly ſheweth that the Semi-circle wants a greater on its Haunches to Counter-Ballance the ſame Weight on the Crown, and how much more Weight is required on the Haunches of the Semi-circle to counter-ballance the ſame Weight on the Crowns of both may be (nearly) diſcover'd by the ſame Method, for by drawing the Cord Line *o*, will cut off one Haunch of both which may be conſider'd as whole Arches and the Difference of Weight be diſcover'd in the ſame Manner for if the Haunch of the Catenarian requires nine hundred Weight the Semi-circle will require Ten, to enable it to ſupport the ſame Weight on the Crown as the Catenarian and the Haunch of the Segment *a*, *e*, *c*, is likewiſe ſubject to the ſame Rule, and requires but ſeven, by Reaſon the Haunch is not ſo much elevated which gives the Weight a greater Gravitation.

In like Manner may the Difference of Weight be diſcover'd in any two Arches, which will always be in Proportion, as the Chord Lines of their reſpective Segments are to one another, or in Proportion, as the Sides of their inſcrib'd Pediments are to one another, which implies the ſame Thing as may be ſeen by the Figure.

In *P.* 50 and 51, the Reader may find I have there explain'd the Nature and Property of the Steel-Yard, and in the next Page have made uſe of its Power, to diſcover what Power a Leaver gains by falling from a Perpendicular to a horizontal Poſition, and likewiſe to prove that all Arches want an Abutment proportionable to the Height they riſe, and as that anſwer'd the Purpoſe ſo far as to appear to me a Demonſtration, I ſhall introduce the ſame Power, and by it examine Mr. *Price*'s Middle Arch, in the Manner following, *Fig.* 62.

Let A, B, C repreſent the Arch propos'd, now if we ſuppoſe, that the half Arch B, C, was in one Stone, and its Weight 28 Tun and a half, a half, and that it was by ſome Power to be lifted upon its Pier *w*, until it come to its Center of Gravity, which may be ſuppos'd to be at *d*, then it is very plain, that the Pier muſt bear all its Weight, and if from thence it was to be let down to a horizontal Poſition, as at *x*, and a Support put under the End, as at *o*, the Support *o*, would bear 14 Tun and one Quarter, and the Pier *w* would bear the ſame Weight, and was it from thence to be lifted up to its proper Place at B, and there ſupported, then will the Pier *w*, bear $20\frac{1}{4}$ Ton, and the Support at B, bear $8\frac{1}{4}$ Ton, for the End B, being elevated, the Support *o*, is releas'd of 6 Ton Weight, which conſequently muſt be added to the Pier; for as this half Arch is ſuppos'd to be in one Stone, it may be conſider'd as a Leaver, and be ſubject to the ſame Laws of Gravitation, as hath before been demonſtrated, and may be explain'd by this Figure.

This Method ſeems to me to give ſome Inſight, whereby the real Weight of the Abutments may be diſcover'd; for if the Support *o*, was taken away, and the other half Arch A, B, was ſet up againſt it in its proper Poſition, that muſt certainly throw the whole Weight of both on their reſpective Piers, but as A, B, is ſet at the ſame Angle, as B, C, they would thruſt each other down, if there was not an Abutment plac'd at A and C, to prevent it. Now, if we conſider, that before A, B was ſet up againſt B, C, the Support *o*, ſupported 8 Tons and a Quarter; therefore the Thruſt of A, B muſt be equal to that Weight, if there was no Friction at *c*, and if ſo, it appears very plain to me, that a Weight of 8 Tons and a Quarter, plac'd at A, and at C, will be a ſufficient Abutment for the Arch, A, B, C; for as ſuch a Weight is a counter Ballance to the Thruſt there will be the Friction of A, B, C, on the Piers for a further Security, which, conſidering the great Weight of A, B, C, may, perhaps, be equal to two Ton more, but this muſt be refer'd to Experiment.

And, if the Arch A, B, C was to be conſider'd in Parts, as the Half A, B, the Weight or Preſſure, would ſtill be the ſame, for by drawing parallel Lines from the Joints to the Chord Line plainly ſheweth how the Weight is diminiſh'd, as appears by the Figure.

By what I have endeavour'd to demonſtrate, it appears very plain, that the Center which is to ſupport the Arch, A, B, C, will be releas'd of 12 Ton Weight, in the Thickneſs of the whole Breadth, which is ſuppos'd to be 40 Feet, and the Number being multiplied by 12, the Produce is 480, which being reducted out of 2320 (which is ſuppos'd to be the Weight of the Whole) the Remainder is 1840, which will be nearly the Weight (when that of the Key-ſtone is deducted out) that will lie on the Center before it can be reliev'd by the Key-ſtone. How much of the Spandrel's Weight will preſs on the Arch is very difficult to diſcover, becauſe it hath a Communication with the upper Pier, or Breaſt-work, which takes off a great deal of the Preſſure, but was that Communication to be deſtroy'd, and it was to be conſider'd as one Stone, and to have no Friction on the Arch, it could then be only ſaid to lean on the Arch, and what Weight that Leaning is may in ſome Meaſure be diſcover'd by the ſame Rule as the former; that is to draw a Line, as *d*, (in the 62d Figure) in ſuch a Manner, that if the Spandrel was lifted up on its lower Point until that Line become perpendicular, it would then be the Center of Gravity, and if the Line *d*, was continued to cut the Arch P, and from thence let fall a Perpendicular to the Chord Line, which if divided according to the Weight of the whole Spandrel, it will give the Weight that will preſs on the Arch if the Line *d*, be ſo drawn as the Quantity of Matter on both Sides are equal, which ought to be regarded in the half Arch, B, C, as well as in this preſent Caſe.

I ſhould not have applied this Power to the Spandrel had it not been to have ſhew'd the Extenſiveneſs of this Method in Reſpect to Arches as well as to other mechanical Operations, not as I will pretend that this Method will diſcover exactly the Weight, or Preſure, of any Arch, but I believe it will be near enough to let a Man know what he is about when he either deſigns or erects one.

But, as the Spandrel will be work'd up with the Upright of the Pier and cramp'd and cemented together, and the Joints diſpos'd of in ſuch a Manner as will take off moſt of its Preſſure, unleſs it be thoſe Stones near the Crown, which have no Occaſion to be laid on until the Key-ſtone is fix'd, and I cannot help thinking, but that it may be fix'd before the Spandrels are begun, provided it have a Bearing on the Center, eſpecially in thoſe Sort of Arches that are of the Catenarian Kind, whoſe Haunches, I dare ſay, would ſuffer no Diſturbance, if the Key-ſtone had a Bearing on the Center.

If this Arch will admit of being work'd up after this Manner there is no Occaſion to allow any Weight for the Spandrel, ſo that then there will be no more Weight to account for (that will lie on the Center) than that of the Arch itſelf, which, according to this Way of Demonſtration, will be no more than 840 Tons, which is ſeveral Tons leſs than ſome Men have imagin'd will lay thereon.

As this Center muſt be forty or more Feet long, I do not ſee any Reaſon to double it, it being able to ſupport the Arch, if the Weight of it was as much more; for if the great Length be conſider'd in reſpect to the Weight, the Weight muſt appear but inconſiderable in regard to the Weight that ſuch a Center may be made to bear, and if the Centers are made with Judgment, and allow'd a firm Foundation, or Bearing, at the Springing it is unknown what a Weight ſuch a Center will bear.

From what hath hitherto been endeavour'd to be demonſtrated, in Reſpect to Arches it appears to me, that their Strength doth not ſo much depend on their Shape, as the Weight they bear, being well adapted thereto; for altho' it muſt be granted, that Catenarian Arches (if conſider'd as independant of any Weight but their own) are the ſtrongeſt of all other, yet if the Weight on their Crowns is not proportionable to the Height they riſe; they may be ſaid to be weaker than a Semicircle, or Arches, of any other Form, if their Weight and Abutments are well proportion'd, and if I may be allow'd to give my Opinion on thoſe Arches, deſign'd by Mr. *Langly*, Mr. *Price* and Mr. *Hawkſmoor*, (which are all I have ſeen that are deſign'd for the Bridge) I muſt give the Preference to that deſign'd by Mr. *Hawkſmoor*, for notwithſtanding the Shape is a Semicircle, the Weight ſeems the beſt proportion'd and the Nature of the finiſhing the beſt adapted to the Situation; but, however that be, it cannot be denied, but that the Arches in either of the Deſigns (if well executed) would ſupport a Bridge over the *Thames*, but then I think it would have been to a better Effect if they had been allow'd a greater Thickneſs of Building over their Crowns, which according to my Way of Thinking they all ſeem to want, eſpecially thoſe deſign'd by Mr. *Langly*, which by Reaſon of its Shape are beſt able to ſupport it, and had he but allow'd a greater Thickneſs between the Crown of his Arches and the Paving of the Bridge, it would conſequently have added a greater Weight, which, in all

Probability, would have prevented that unequal Preſſure occaſion'd by the Declination of the Bridge from having a bad Effect on the Arches, which in order to prevent hath leſſened the Weight on the Haunches by cylindrical Vacuities proportionable to the Difference of their Preſſure, which is monſtrouſly abſurd.

But this I conceive Mr. *Langly* hath introduc'd through Ignorance; for had he conſider'd, that the Weight on the Haunches is not ſo great as it appears to be, and that what is, may be conſider'd as an Abutment, he could never have imagin'd, that the Unequalneſs of their Preſſure would occaſion their becoming rampant and falling down, if the next adjoining ſhould chance to be remov'd by either Time, or Accident.

I ſay, if he had laid a greater Weight on the Crowns of thoſe Arches he deſign'd for the Bridge, and omitted thoſe cylindrical Vacuities he hath there introduc'd, his Arches would then have appear'd to me more capable of Duration, and this he might eaſily have perform'd; for if the Surface of the Bridge would not admit of being carried any higher the Arches might have been made lower, and by that Means have gain'd a proper

Thickneſs between their Crowns and the Paving of the Bridge.

This Alteration, I muſt own, would occaſion a greater Thruſt from the Crowns to the Abutments below, but as the Upright of one of his Piers taken from the Springing of his Middle Arch, conſider'd as one Foot thick, contains above 112 Ton Weight, it would be more than ſufficient to counter-ballance the Weight or Thruſt from the Crown, and be able to ſupport any of his Arches independent of each other, for carrying the Building a convenient Height above the Arches, not only loads the Arch, but the Pier alſo, which muſt be conſider'd as an Abutment to the Weight laid on the Crown, for it is not the Extent of an Abutment, but the Solidity that ought to be conſider'd as moſt capable to reſiſt any Force, or Power, that wants to remove it; therefore as the Abutment increaſes in Proportion to the Weight laid on the Crown, I cannot ſee how an Arch can be well over-loaded if their Abutments are good, and there is no more Weight laid on than the Foundation will bear, which, I muſt own, ought to be conſider'd.

But to ſtrengthen this Argument, I think, the Arches of *London Bridge* may be conſider'd as a very good Precedent to ſhew what Weight Arches will bear, for as the Diſtance between the Crowns of thoſe Arches and the Paving of that Bridge, by far exceeds any that is deſign'd for the new One, and if the Materials are the ſame the Weight muſt exceed in the ſame Proportion, and add to that the Load of Houſes, and then conſider the Length of Time that thoſe Arches have ſupported that Weight. I ſay, if theſe Things are conſider'd, I cannot ſee any Occaſion for our modern Deſigners to be ſo fearful of overloading theſe Arches, and omitting a Weight or Thickneſs where it is moſt wanted.

This I ſhall endeavour to make appear by the following Compariſon, which, notwithſtanding it being a low one, may chance to be more convincing than any Argument I can make uſe of, that is, (if ſmall Things may be compar'd to great) I don't know any Thing that appears ſo much like a Bridge ſupported by Arches, as a long Board cut in Pidgeon-holes. Now I think it cannot be deny'd by any Man that hath any Notion of Building, that the nearer thoſe Holes or little Arches are cut to the upper Edge of the Board, the weaker ſuch a Board will be, and conſequently the more unfit to ſupport any Weight that ſhould be roll'd over it. Therefore, if this Compariſon be juſt, it muſt appear very plain that the Strength of all Bridges (in reſpect to heavy Burdens paſſing over them) muſt depend on the Thickneſs or Strength of Materials that are work'd over their Crowns.

For if that thickneſs of Materials be conſidered as a Quantity of Matter at reſt, that is to receive a leſſer Quantity in Motion, it muſt certainly be neceſſary to ſo proportion thoſe Quantities of Matter, that the Leſſer will give no Diſturbance to the Greater, for it cannot be deny'd but that a leſſer Quantity of Matter in Motion may diſturb a greater Quantity that is at reſt, therefore it's very reaſonable to think that heavy Burdens paſſing over any Bridge, whoſe Quantity of Matter or Materials on the Crown is not ſufficient to reſiſt the Motion of the Burden paſſing over, muſt in Time ſuffer Damage; for its well known that ſo ſmall a Weight or Quantity of Matter as a Coach and Pair, by moving with a ſwift Velocity (over pav'd Stones) doth very often affect the Houſes of ſeveral Streets in *London*, by cauſing a very ſenſible Tremulation in the Buildings thereof.

I ſay, this may chance to be of an ill Conſequence to any publick Bridge ſupported by Arches that hath not a ſufficient Thickneſs of Materials laid on their Crowns that is able to reſiſt the Jolts and Surges of any Burden that may chance to paſs over it without ſuffering any Diſturbance thereby, and it is from this Conſideration that I have before obſerv'd (in *p.* 54) that the Weight of Houſes erected on *London*-Bridge hath very much contributed to its Preſervation, by preventing thoſe frequent Strokes and Shakings that it muſt otherwiſe have felt, if ſuch a Weight had not been laid thereon, and if Weight hath been a Benefit to the Old Bridge it muſt conſequently have the ſame Effect on a New One.

As to laying the Foundation of the Piers in Coffers, or Floats, I have before (in *p.* 60.) ſhew'd my Diſlike, and have there given a Method that ſeem'd to me more practicable, but ſince my reading two Pamphlets, and finding that ſeveral ingenious Men have thought it worth their Conſideration, it hath induced me to think more cloſely on the Subject, therefore I ſhall venture to propoſe another which will be leſs expenſive, and to a better Effect.

In my former Method, I propos'd Piles and Planks to be dovetail'd, grov'd together, and ſharpen'd at the lower Ends and ſhod with Iron, in order to drive into the Foundation round the Plan of the Piers to keep out the Water until the Foundation was laid, and carry'd on above High Water Mark, which I believe would have anſwer'd the End propos'd, but as conſidering the

Accuracy of the Workmanſhip that will be requir'd in ſuch a Performance, and the Time it will take up to make ſo many Grooves in a Dovetail Form, and alſo the Difficulty that will attend the getting of them aſunder in order to make them drive again, hath occaſion'd my altering of my firſt Deſign to the Method following.

This is inſtead of the before-mention'd Planks and Piles that was propos'd to be dovetail'd together and drove ſeperately into the Foundation, I here propoſe they ſhould be made into Floodgates which will have no Occaſion to be grov'd but only join'd together and made in two Thickneſſes after the common Manner of making ſuch Gates, as is ſhew'd in *fig*. 63. only the lower End of the long Planks muſt be ſharpen'd, and the Sides or Edges ſo ſharpen'd ſhould be bevel'd off in ſuch a Manner as to leave an Edge in the Middle that when they are well ſhod with Iron they may the better cut their Way into the Foundation, the Piles muſt be grov'd to receive the Gates, and to be done in ſuch a Form as will circumſcribe the Plan of the Pier, obſerving to leave Room for Men to Work.

The Diſtance of the Piles to be about four Feet which will terminate the Width of the Gates which are to be drove into the Foundation between every two Piles, which for the better Conveniency of driving muſt have a Capſill tennanted on to the upper End to raiſe the Weight whoſe Thickneſs ought to be the ſame as the Capſill and the Shape like that I have given at the Top of the Gate, and to ſlide in Groves to give it a proper Direction, after the common Method of driving of Piles.

Such a Range of Gates and Piles (as I have obſerv'd before) by Reaſon of their great Length will want to be ſtrengthen'd to make them able to reſiſt the external Preſſure of Water which (undoubtedly) will be very great. Therefore in this Caſe, as in the former, there muſt be other Piles drove in (without-ſide the Range) 4 or 5 Foot diſtance from every ſecond or third Pile belonging to the whole Range, and brac'd thereto Diagonal Ways as near to the Bottom as the loweſt Water will admit, which will add a great deal of Strength to the whole Range and prevent the Weight of Water from puſhing it down.

Such a Method if the Materials are good the Work well perform'd and carefully executed is very likely to keep out the external Water, when the internal is all laved or pump'd out, for I cannot conceive that the Leakes will let in more Water than a Chain Pump or two will be able to diſcharge, by Reaſon all thoſe Leaks that will happen above Low Water Mark may be ſtop'd from without, and thoſe that happen below may be ſtopp'd from within as the internal Water ſinks, therefore, I cannot ſee any Room to doubt of the Foundation being laid dry, or at leaſt dry enough for Workmen to lay the Foundation of any of the Piers, and to work with the ſame Safety, as if the whole Current of the River was turn'd into ſome other Channel.

I ſay, this Method is the more likely to anſwer the End propos'd, by Reaſon it is nearly the ſame that hath been ſo long practic'd by Millwrights to dam up large Heads of Water for the Uſe of Mills in Rivers which they generally turn into ſome other Channel, and by that Means can come at the Bottom of the River to lay in a Ground Sill for the Gates to ſhut, which are commonly made to ſhut ſo cloſe as to let no Water paſs by when the Gates are ſhut.

But to compenſate for ſuch a Sill which cannot be laid with any Certainty in the River *Thames*, I have propos'd the Gates to be made in ſuch a Manner as will drive into the Bottom of the River, which appears to me to be a better Security to prevent their Blowing at Bottom, than any Ground Sill be it never ſo well bedded to the River's Bottom, and as the ſharpen'd

Ends of ſuch a Gate taken together will contain but a little more Solidity than the ſharpen'd End of a ſingle Pile, that is one Foot Square, it's very likely to want but a little more Power to drive it in, and conſidering the Gate will be in Parts, it may, perhaps, require leſs, but this I refer to Experiment.

As to the Nature of the Foundation or Bottom of the River where the Bridge is to croſs over, I muſt own, that I am unacquainted therewith, but it hath been obſerv'd that it conſiſts of two Stratums, the one Clay and the other Gravel; and in order to ſuit both, they have propos'd two Sorts of Coffers, or Floats, for the laying the Foundations of the Piers, but the Method that muſt be made uſe of to make the Materials of one ſerve again for another is what is conceal'd, but whether they are conceal'd for the Reaſons there given, or from ſome other Motives, I will not pretend to determine.

But however that be, I believe it will appear from the Nature and Form of thoſe Materials I have propos'd for that Purpoſe, that after they have perform'd their Duty to the firſt Piers they will admit of being drawn out and drove in again (to the ſame Effect) for the Second, and if there is but one Pier to be carried on at the ſame Time it is not impoſſible for one Set of

Gates and Piles to ſerve for the whole Bridge, for be the Stratums at the Bottom, either Clay or Gravel, if the Gates and Piles be well ſhod with Iron, there is no Fear, but they will make their Way into the Foundation.

And if the Bottom of the River conſiſts of two ſuch Stratums as Clay and Gravel, it is reaſonable to think that the Gravel is the lowermoſt, and muſt appear in the Channel, and if ſo, according the River's Section, the Stratum of Clay cannot be of any great Thickneſs, but may be clear'd off from the Gravel at a leſs Expence, and to a better Effect, than to drive in a great Number of Piles, and after that to be at the Expence of Oak Planks, in order to gain a Foundation, when perhaps the Sinking of two or three Foot may ſave that Expence, and have a better Foundation, than can be expected from any Timber whatſoever, for unleſs it can be demonſtrated, that Timber is as durable as Stone, (I think) it ought to be rejected as unfit to ſupport any Stone Building, eſpecially one that is deſign'd for the Uſe of Ages to come.

I am not inſenſible, that Oak-Timber will laſt (if buried in Earth or Water) many Years longer than if it was expos'd to the different Mediums of our Atmoſphere, which is continually ſhrinking and ſwelling all ſuch porous Bodies, that in Time deſtroys the Coheſion of their Parts, and occaſions them to molder away and become reduc'd into their firſt Principles. But, notwithſtanding this Difference, it cannot be denied, but that Stone is more durable than Timber; therefore it would be very improper to put the Weak to ſupport the Strong, and for thoſe who have a Mind to ſee the Effect of ſuch a Foundation may go no farther than the New Church at *Weſtminſter*, where they may ſoon be convinc'd by the ſeveral Fractures that are viſible in that Building, that Piles and Planks (which is Part of that Foundation) is an improper Baſement to ſupport a Stone Bridge over the River *Thames*.

But to give the greater Credit to ſuch a Propoſal, the Author hath endeavour'd to perſuade us, that *London Bridge* hath no other: But this by way of Suppoſition, and I do not ſee why any Body elſe may not (with as good Reaſon on their Side) ſuppoſe the contrary, for if the great Weight of that Bridge be conſider'd, and the many Years it hath been ſupported by the Foundation, there is but little Reaſon to believe it to conſiſt of Piles and Planks, but rather of ſome good hard Stone well bedded on a Stratum of firm Gravel that hath been able to reſiſt ſo great a Preſſure for ſo many Years.

Neither can I ſee any good Reaſon for Mr. *James* to ſuſpect the River's Bottom of being inſecure, and not able to ſupport a Stone Bridge; for it is well known, that where the

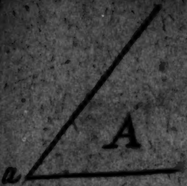
Foundation of Roads are become inſecure, and have a proper Deſcent to carry off a Current of Water when let in upon them. I ſay, ſuch Roads (if they are not a Clay) will become more ſecure, for Water being let in upon them, and ſeldom want any other Repair.

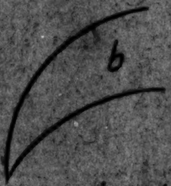
Therefore it is reaſonable to believe, that the Bottom of the River *Thames* cannot be the worſe for ſo large a Current of Water paſſing over it, but the better, and if the ſame Stratums are to be met with, at the *Wooll Staple*, or *New Palace Yard*, or at the *Horſe Ferry*, as are at *London-Bridge*, there is no Room to doubt of their ſupporting ſo great a Weight.

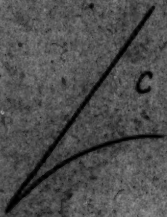
I might have enlarg'd my Obſervations on what others have publiſh'd relating to the Bridge. But as I have already carried this Performance to a greater Length than I firſt deſign'd it, and the Time ſeems to be ſo near at Hand that the Bridge muſt be begun; I ſhall forbear to make any further Remarks thereon; but only obſerve, by way of Caution to thoſe it may concern that good Nature hath always been eſteem'd a very amiable Quality in an Author, and where that is wanting the Force of his Arguments are very often loſt, for when a Man is angry his Reaſon is generally ſuſpended, and he ſeeth Things through a falſe Medium, and what he hath to ſay againſt an Adverſary at ſuch a Time ought not ſo much to be rely'd on, as if it had been the Reſult of a cool and deliberate Conſideration; therefore, I think, there ought to be ſome Allowance in Caſes of this Nature, and before we cenſure (too raſhly) the Miſtakes of others, we ought to conſider thoſe of our own.

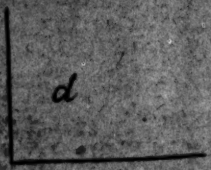
I ſay, ſuch a Reflection if it did not make us over-look the Miſtakes of others, it ought to at leaſt to direct one of our Eyes towards their Merit; for it is but reaſonable, for every Man that pretends to have any Merit of his own, to have ſome Regard to the Merit of others, and if a Man is not inſolently ignorant he ought to merit our Compaſſion rather than Contempt; for my own Part I am ſenſible of this Imperfection in our Nature, and ſhould be very unwilling to affirm any Thing as poſitive that will not bear Demonſtration, eſpecially any Thing of ſo precarious a Nature as the laying a Foundation for a Bridge over the River *Thames*, which nothing but Experiment can juſtify to be right, for notwithſtanding what I have propos'd, for that Undertaking, may appear to me to be practicable; it may appear otherwiſe to thoſe of a more diſcerning Judgment, who (very likely) may propoſe better of their own, which if they do, it will give me no Manner of Concern, becauſe I have no Expectation of any Fee or Reward whatſoever; therefore I ſhall have more willingly offered what I have ſaid (in reſpect to the Bridge) to the Peruſal of the Publick, hoping they will be ſo good-natured as to excuſe the Want of fine Language, or ſome other Defects that may (very likely) be found in this Performance, which I ſhall now conclude.

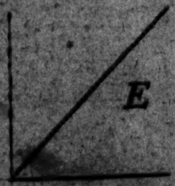
FINIS.

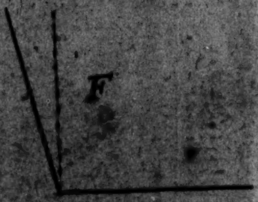


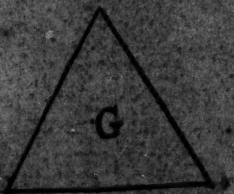












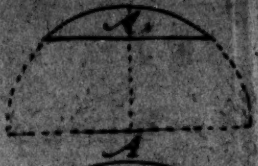


Fig. 1

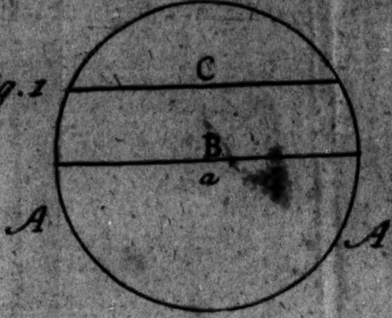


Fig. 2

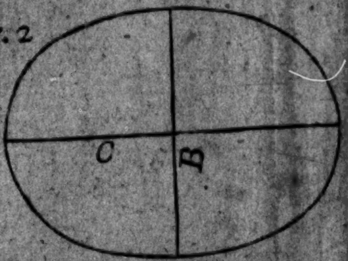


Fig. 3

Fig. 4

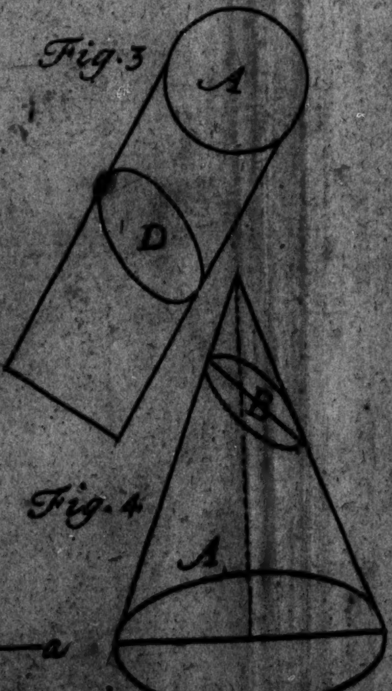


Fig. 5

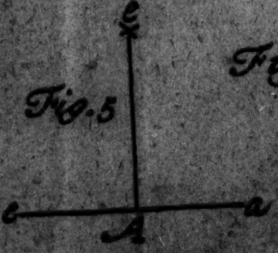


Fig.14

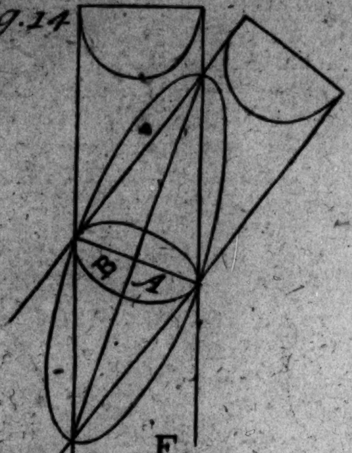
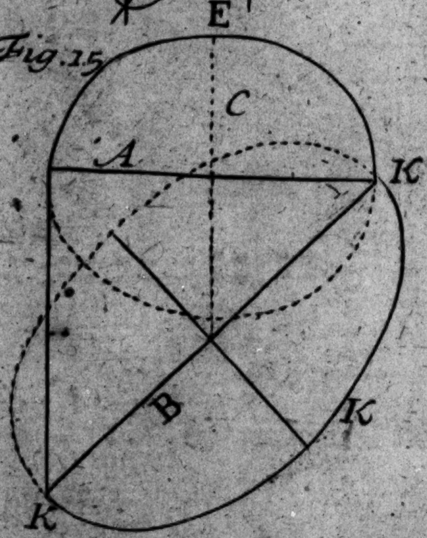


Fig.15



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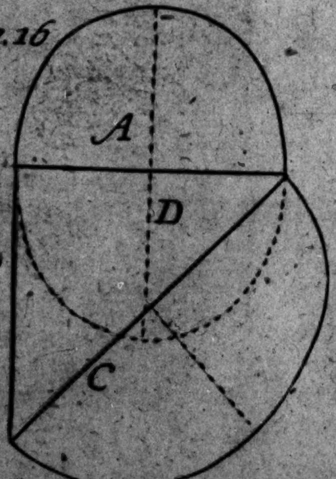

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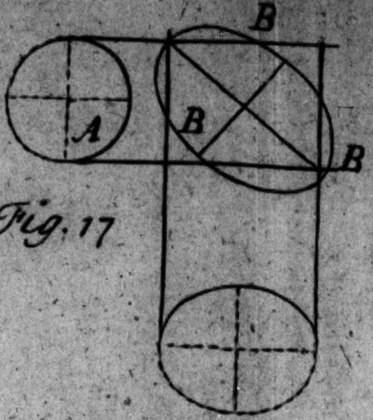

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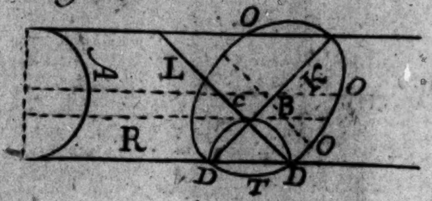

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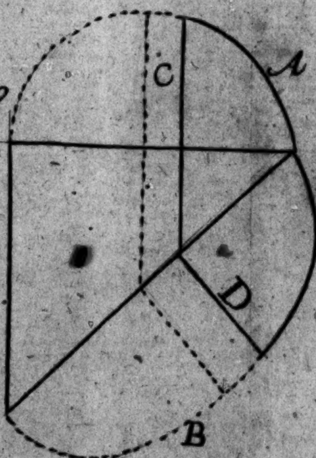

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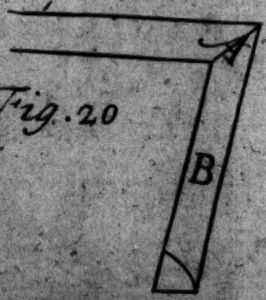

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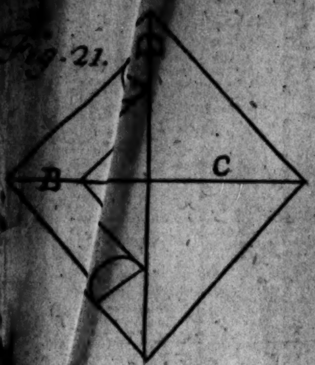

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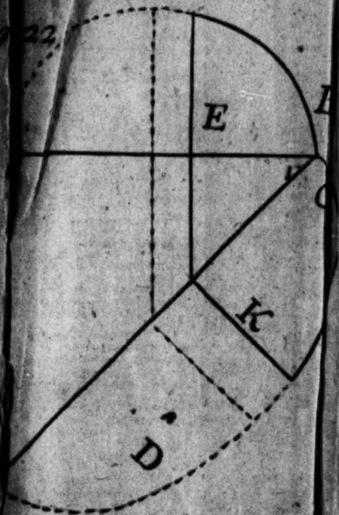

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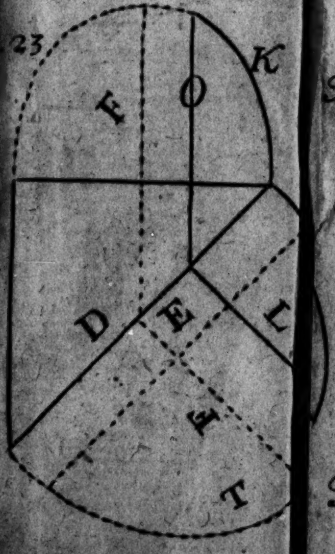
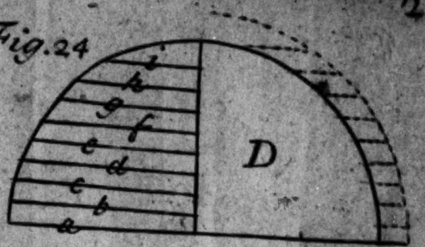


Fig.24



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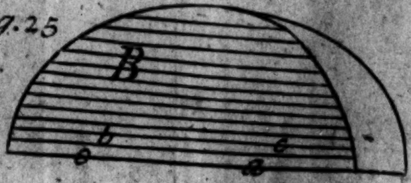
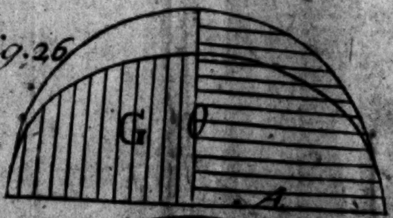


Fig.26



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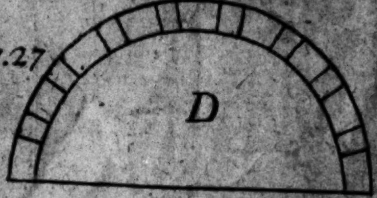

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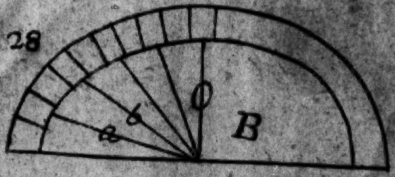

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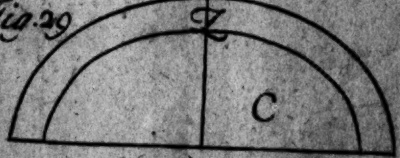

Fig.30

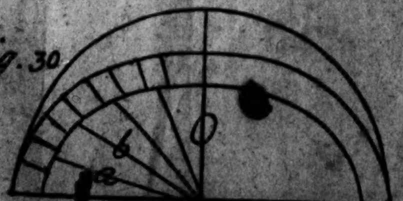

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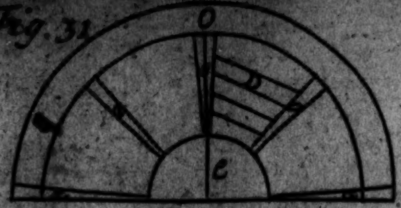
Fig. 31



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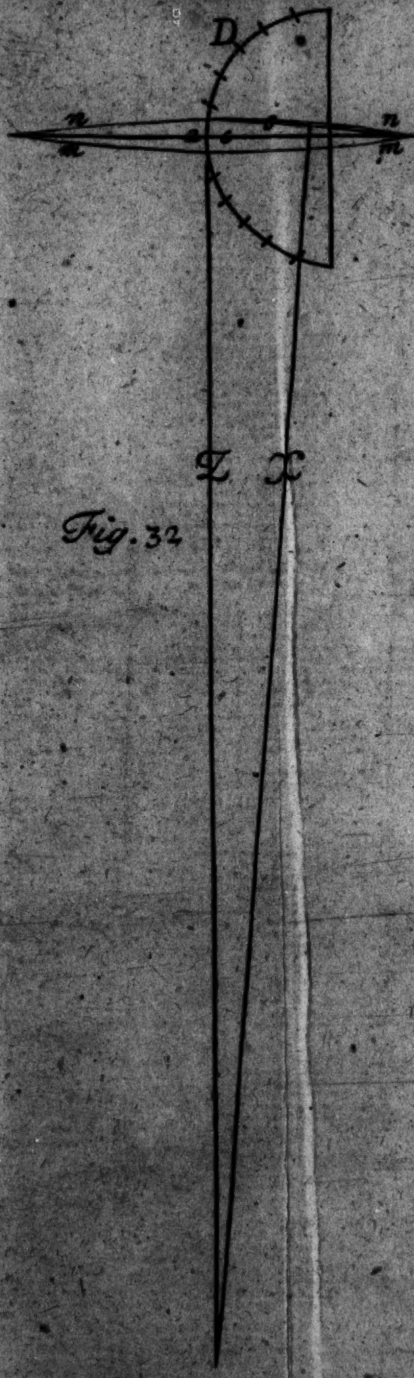


Fig. 33

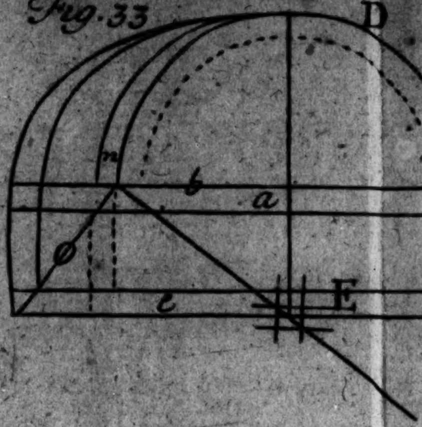
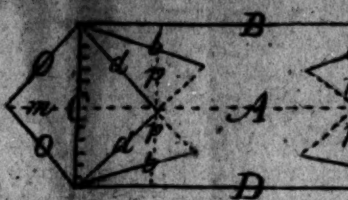


Fig 3



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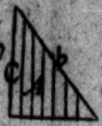

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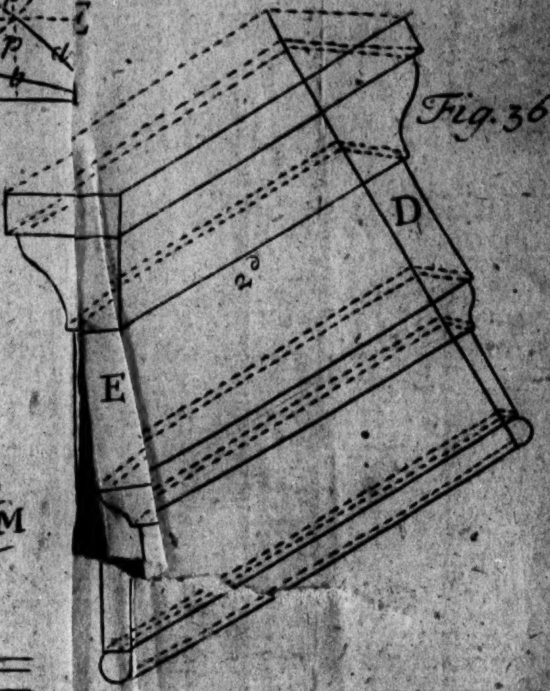

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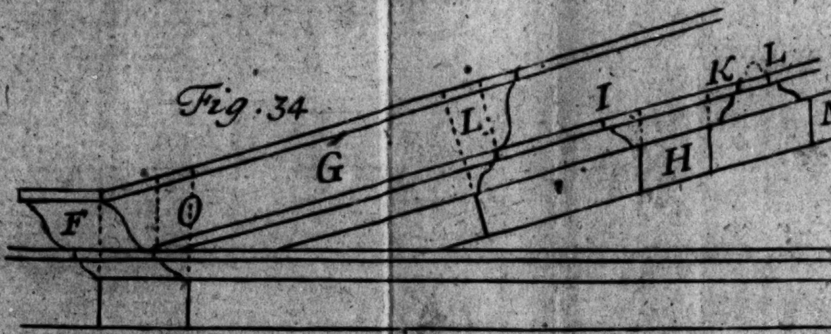

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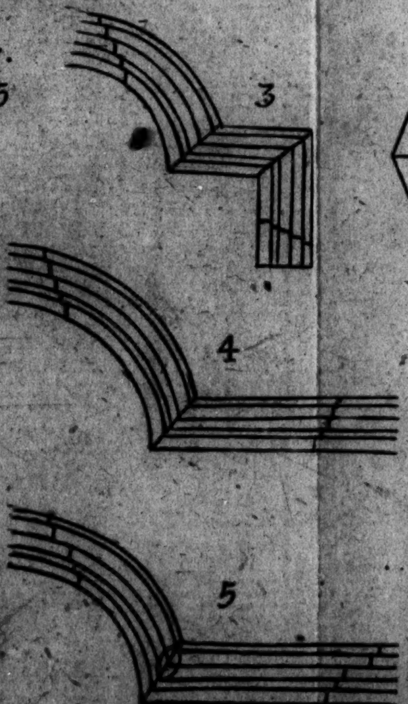

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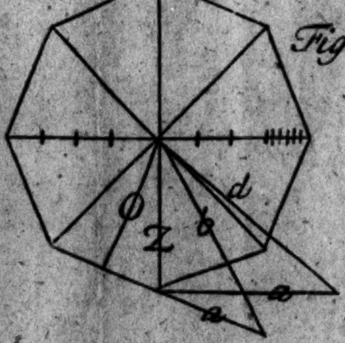

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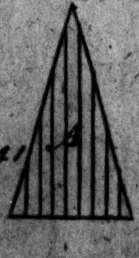

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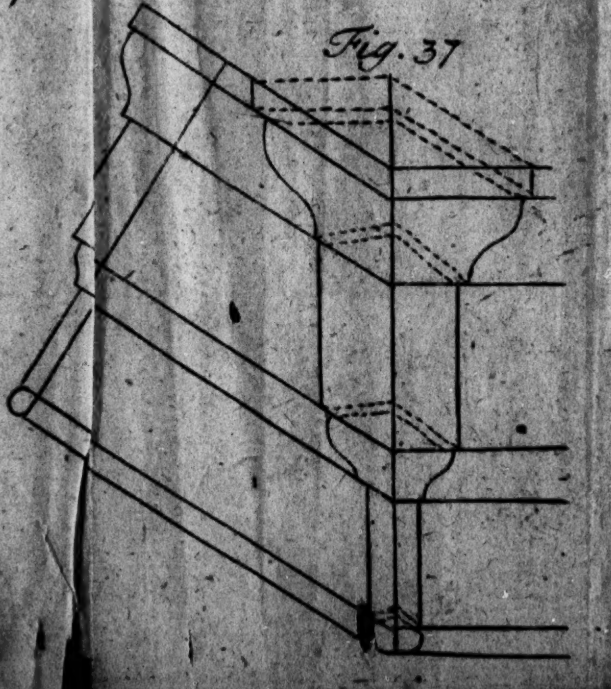

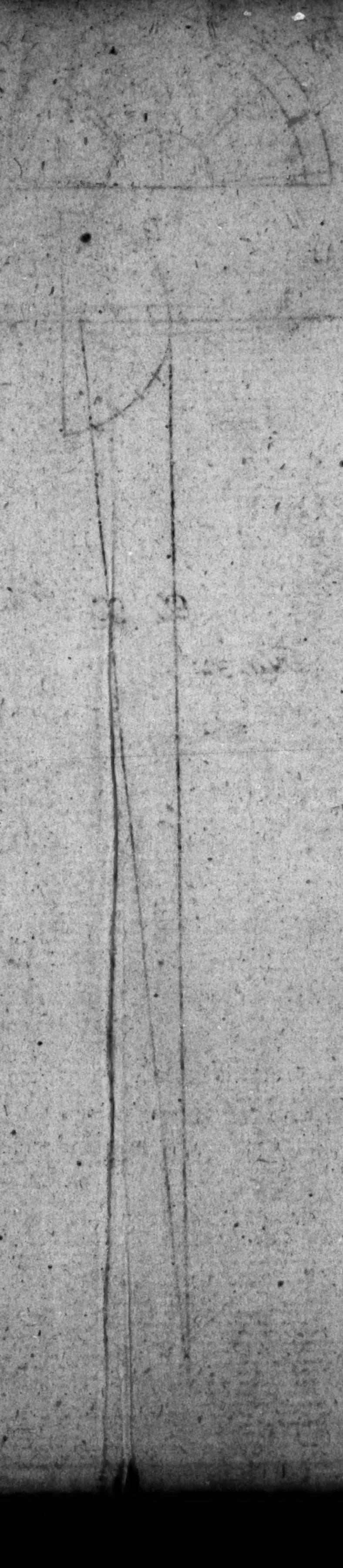

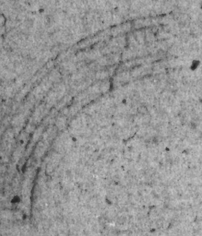

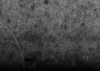

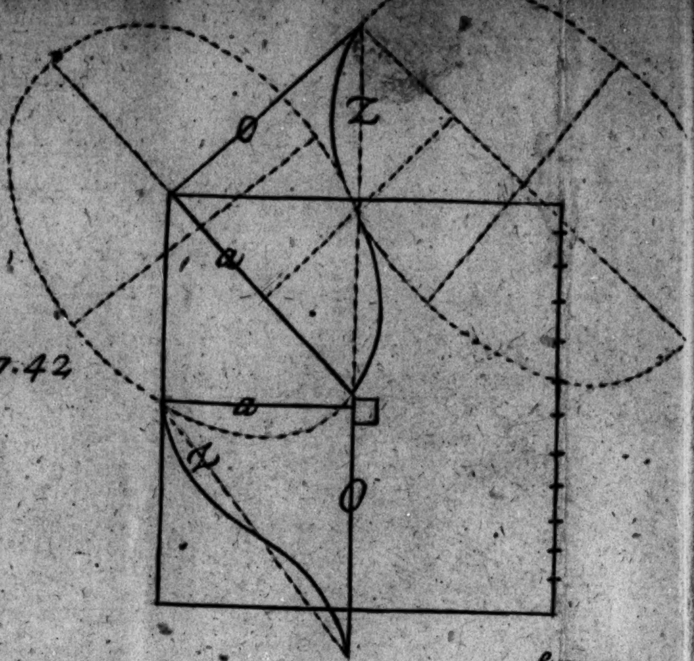

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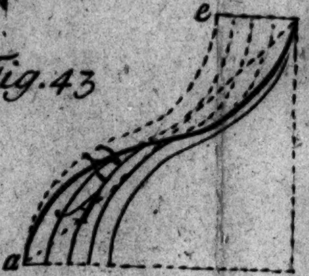

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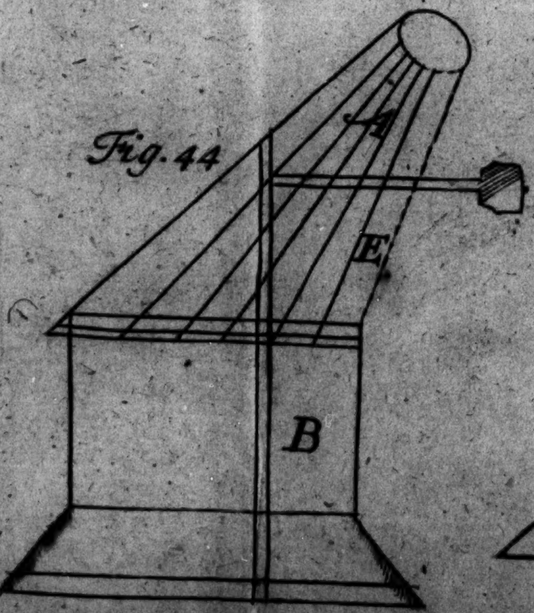

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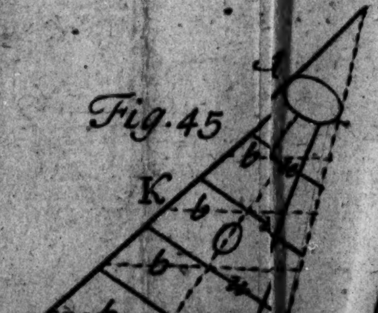

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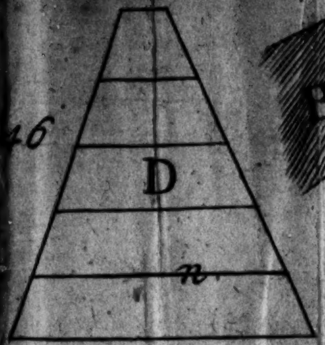

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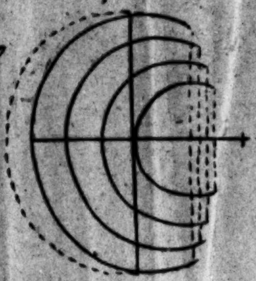

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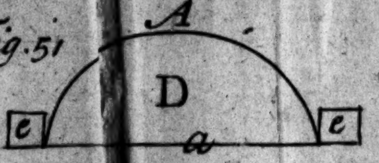

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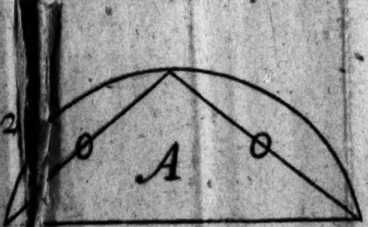

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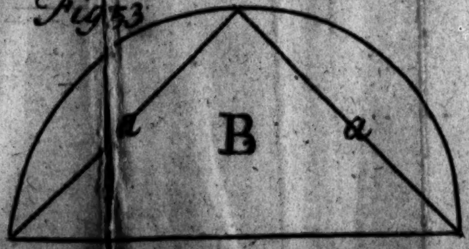

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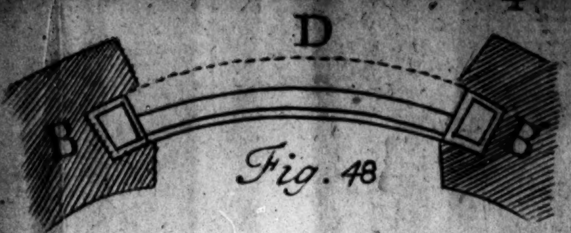

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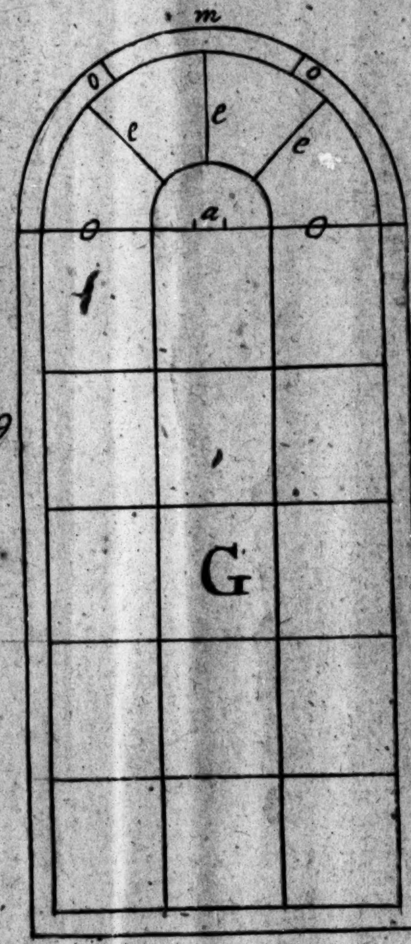

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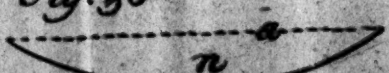

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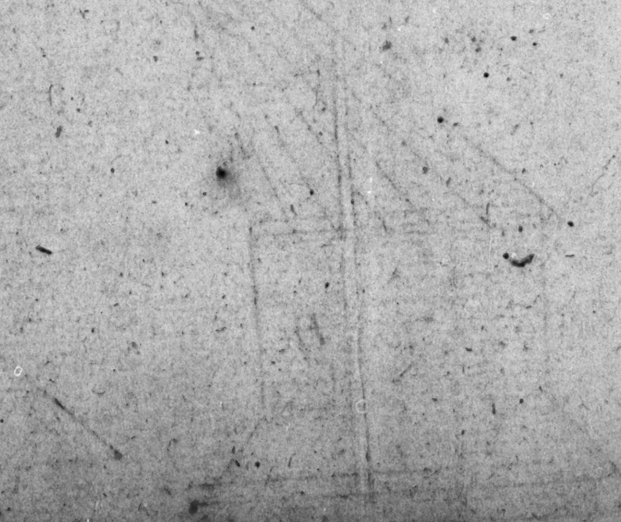

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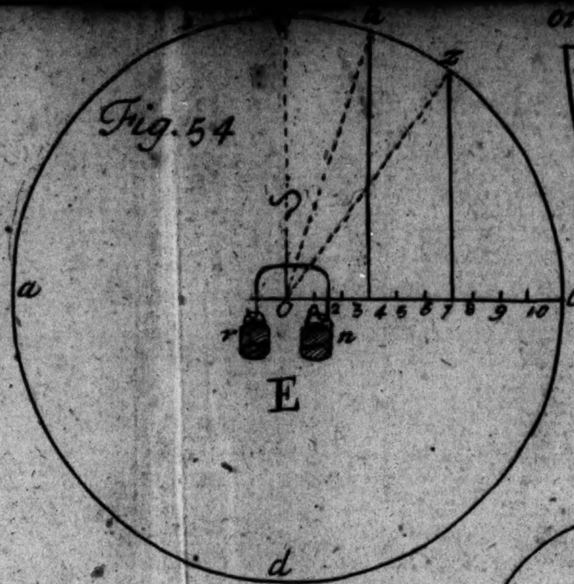

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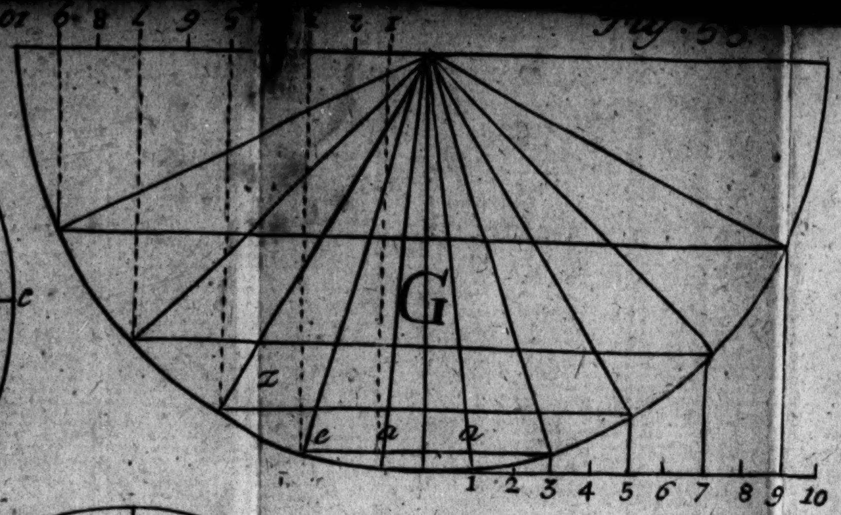

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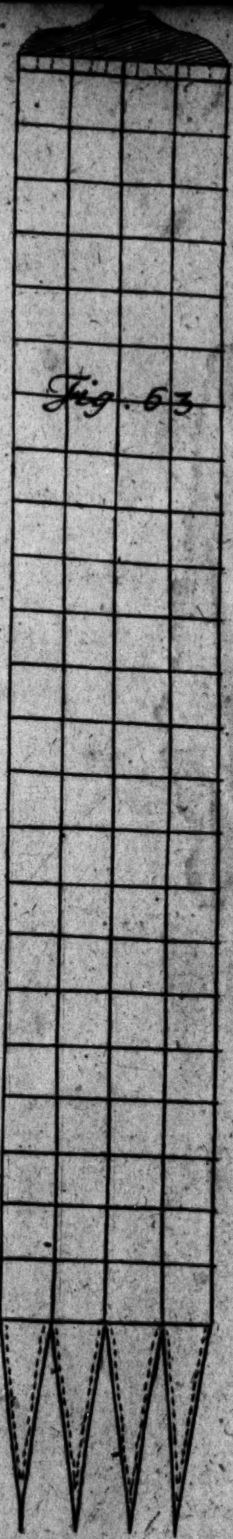

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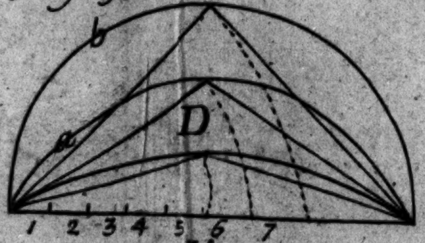

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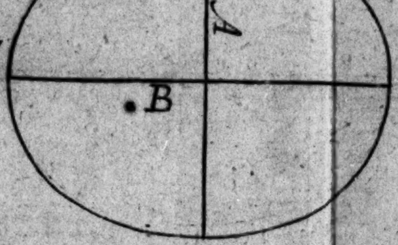

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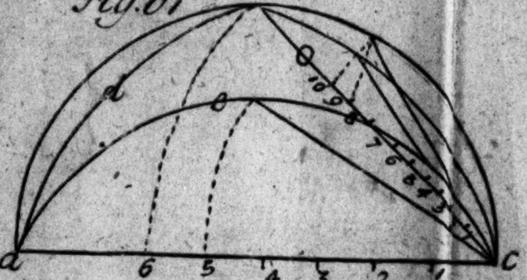

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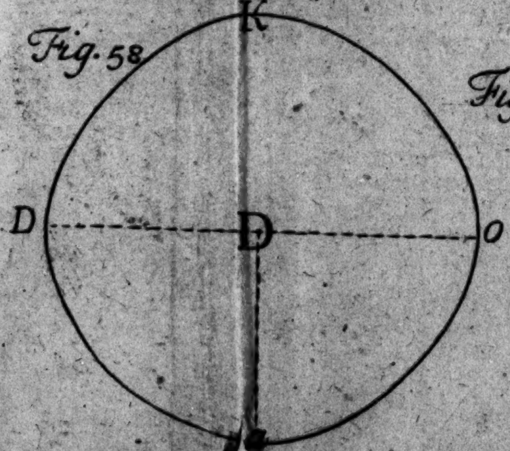

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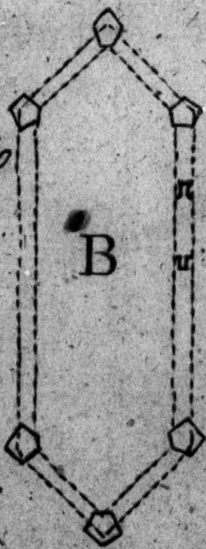

Fig. 62

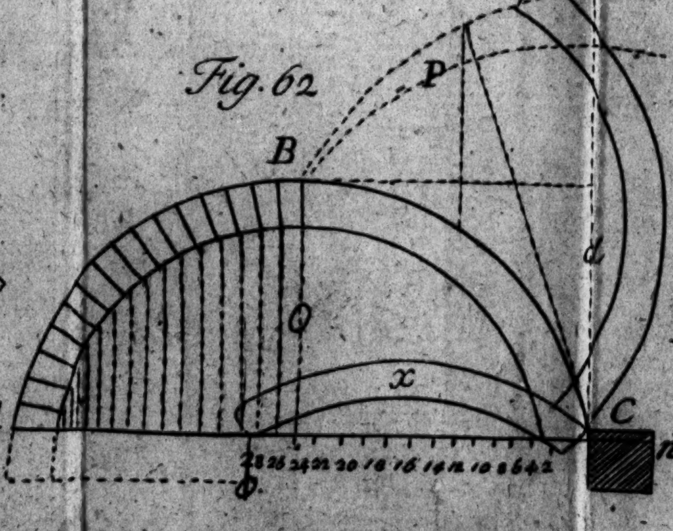

Fig. 59